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APR 8 – 1960

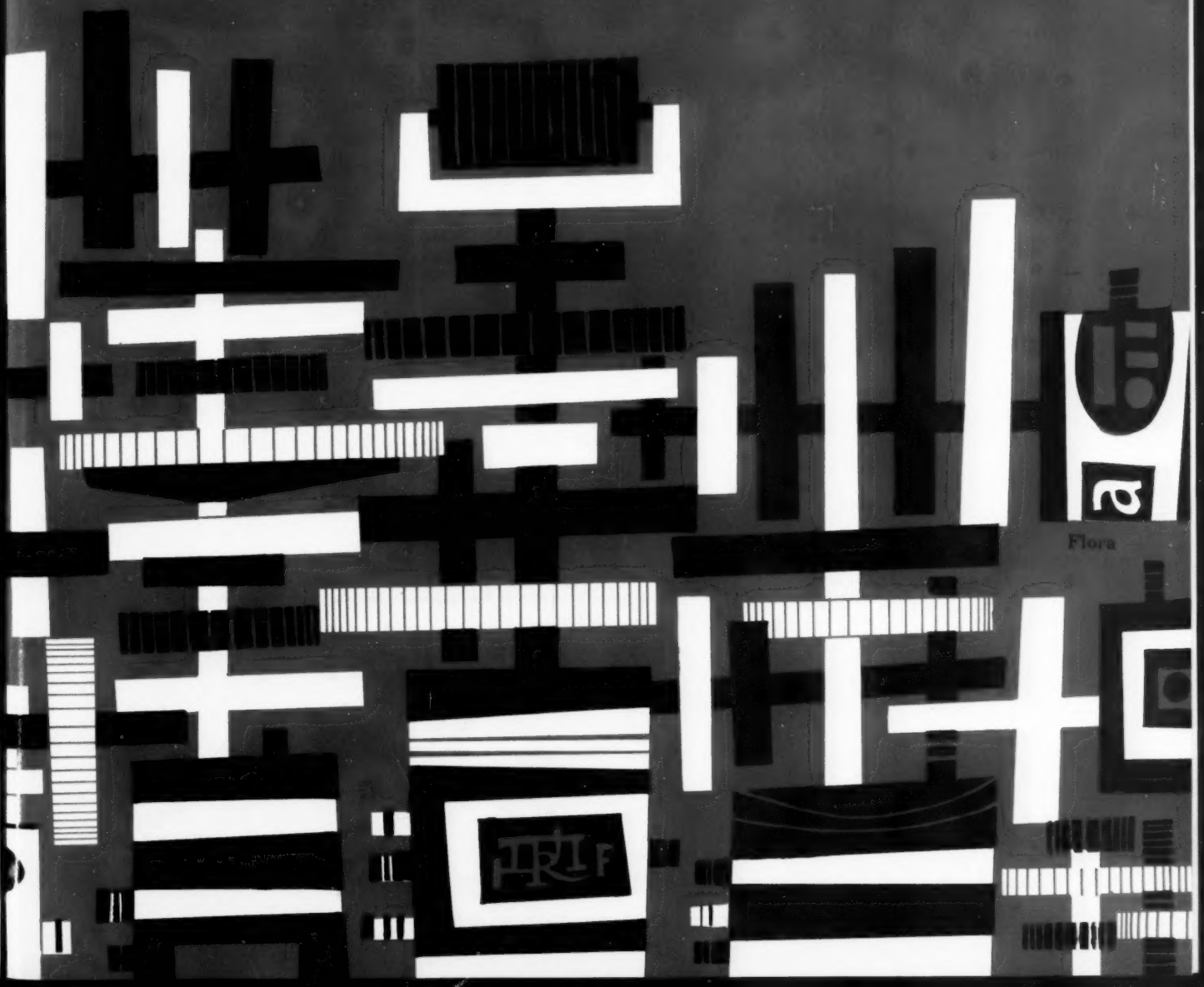
ELECTROMECHANICAL

components & systems | DESIGN

MARCH 1960

in this issue · components digest no. 13

miniature magnetic clutches and brakes



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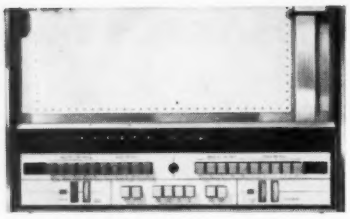

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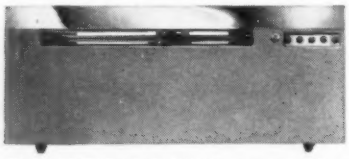

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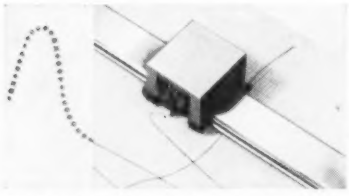

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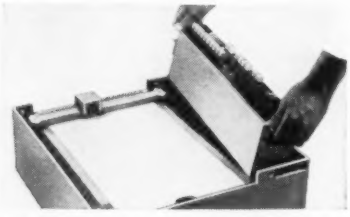

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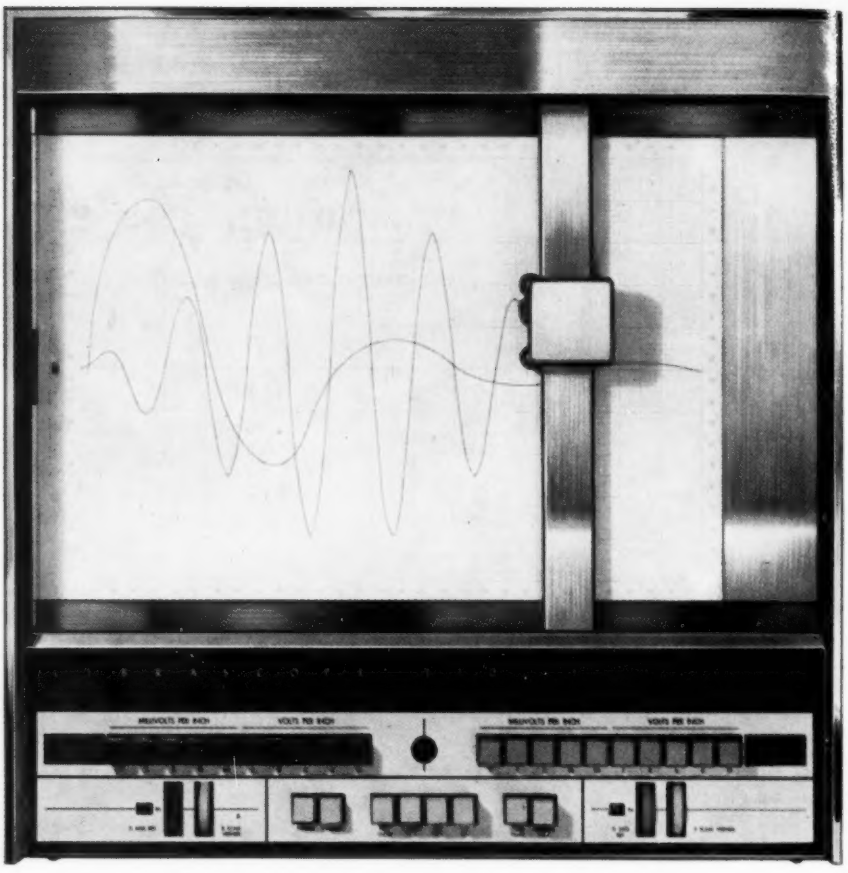

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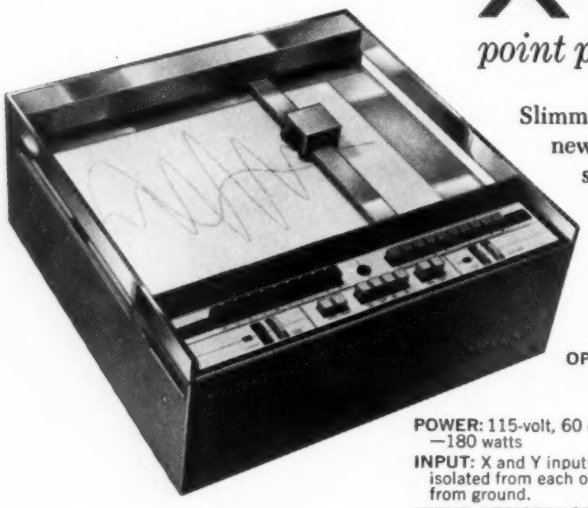

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ELECTROMECHANICAL
components & systems DESIGN

The Sourcebook of Design Ideas in Applied Electromechanics

MARCH 1960 • VOL. 4 NO. 3

THE LIBRARY OF CONGRESS SERIAL RECORD APR 8 - 1960

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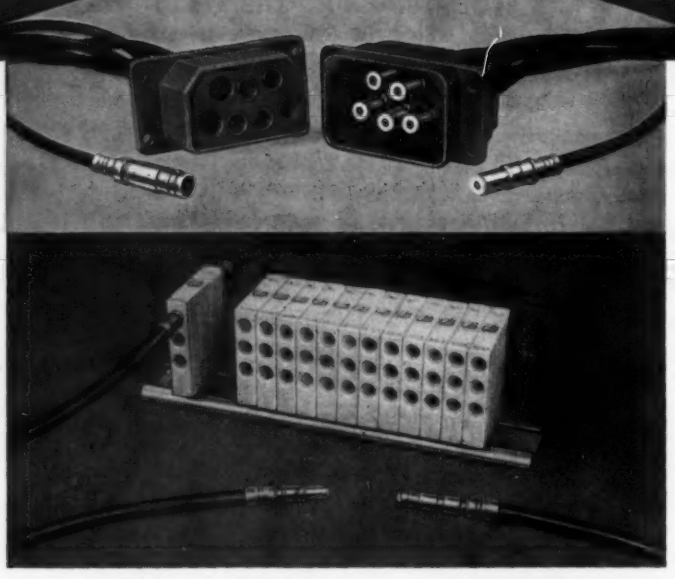

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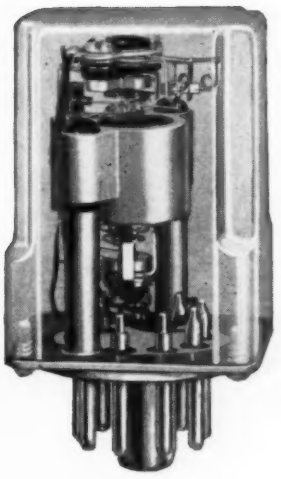

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150	12	1.379	⅜	⅜, 1, 1⅛, 1½	24	paper, mica, bakelite, or nylon	bakelite or steel
200	8	.960	¼	⅜, ½, 1⅜2, 1	16	paper or mica	steel
500	12	1.506	.359	⅜, 1, 1⅛, 1½	24	paper or mica	steel
700	14	1.812	⅜ ½	1⅛, 1½, 1⅞, 2	28	paper	steel
900	13	1.600	⅜	1⅛	26	paper or mica	steel
2700	7	1.380	⅛	1, 1⅛ 1½	7 or 14	paper or mica	steel or bakelite

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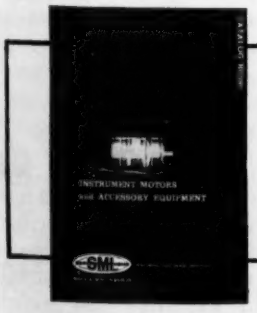

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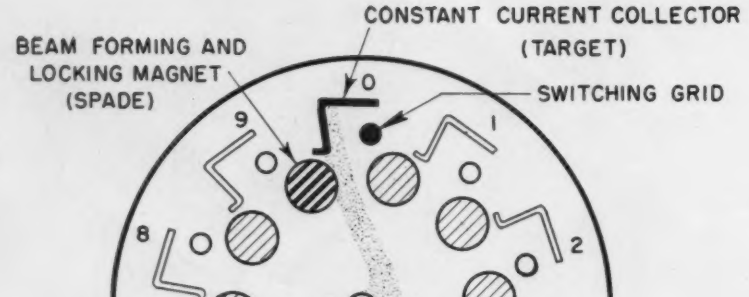

Fig. 1 Cross section of the Beam-X switch.

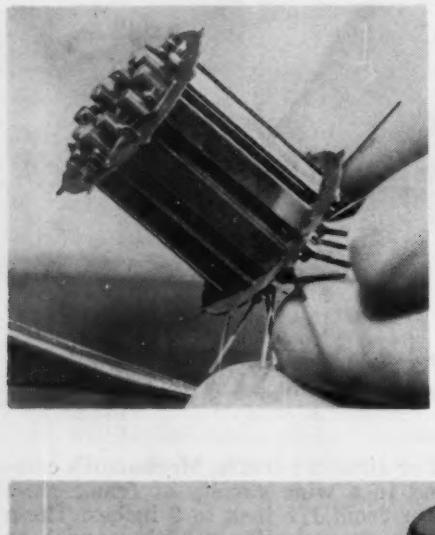

Fig. 2 All 31 parts of the cage assembly are automatically assembled by means of a special vacuum fixture which securely imbeds each element in the two supporting mica wafers. The automatic nature of this operation assures the positioning of the elements to extremely close tolerances and is a big factor in the reliability and reproducibility of the device.

Fig. 3 The Beam-X switch as a transistor decade counter. Module is designed for counting applications to frequencies of 110 KC and provides 10 electrical outputs for activating visual displays, printers, and for preset counting functions. System uses only 56 components. A comparable all transistor counter would require 146; thus, multicomponent unreliability is greatly reduced.

ELECTRONIC DECIMAL SWITCH

Small Rod Magnets Within A Vacuum Direct An Electron Beam To Any One Of 10 Positions.

Merely by varying the associated circuitry, designers can use a new switch called the Beam-X, to perform the digital functions of counting, distributing, multiplexing, sampling, coding, timing, gating, matrixing, dividing, decoding and converting. The Beam-X switch uses small rod magnets within a vacuum to control the position of an electron beam to any one of ten output positions. The result according to Burroughs Corporation's Electronic Tube Division, is a decimal switch reduced in size, weight, cost, and power as to outperform all existing vacuum, magnetic, and solid state devices.

BASIC CONSTRUCTION

The Beam-X switch, though functionally similar to its predecessor, the beam switching tube, is a completely new device 10 times lighter (1½ ozs.), times smaller (3 cu. inches) and the price (less than $25.00 in small quantities). Fig. 1 shows a cross-section of the Beam-X switch. Cage assembly (Fig. 2) which is the heart of the switch, consists of 31 elements. At the center of the cage assembly is the oxide coated cathode which is the electron source for the switch. Located in symmetrical arrays around the cathode are: ten permanent rod magnets (spades) which perform the function of forming and locking the electronic beam to one of the ten output positions; ten output elements called targets which collect the electron current; and ten switching grids which perform the function of switching the electron beam from one position to the next. Connecting wires are attached to the cage assembly and the entire unit is mounted on a glass stem whose 26 pins provide the electrical input and output connections for the switch. A glass envelope is placed over the mount assembly, and the glass sealing and air evacuation operations are performed. Compatibility of the switch with transistor circuitry is shown in Fig. 3.

MAJOR ADVANTAGES

The following considerations lead Burroughs Corp. to claim that this new switch is "the most nearly perfect switching device": it answers a major problem of multi-component unreliability. As an example, the switch

eliminates 90 transistors, diodes and resistors in a typical ten-position switching application. Each of its ten positions has (a) memory, (b) constant current output, and (c) positive switching elements to ensure stability of operation. It may remain stationary indefinitely or switch at speeds in excess of ten megacycles. It is flexible and efficient with respect to B+ operating voltages. To meet specific current range requirements the device may be operated from wide ranges of B+ voltages as low as six volts driven directly by transistors, and constant current output voltages as high as 200 volts when used in vacuum tube circuits. All of the B+ current is put to useful work either in locking the beam or as constant current output. Its switching characteristics appear to have unlimited versatility. It may be interconnected as a distributor of any number of positions less than or greater than ten; it may switch sequentially or at random and may be preset to any position; and may be reset from any position to any other position in less than one microsecond.

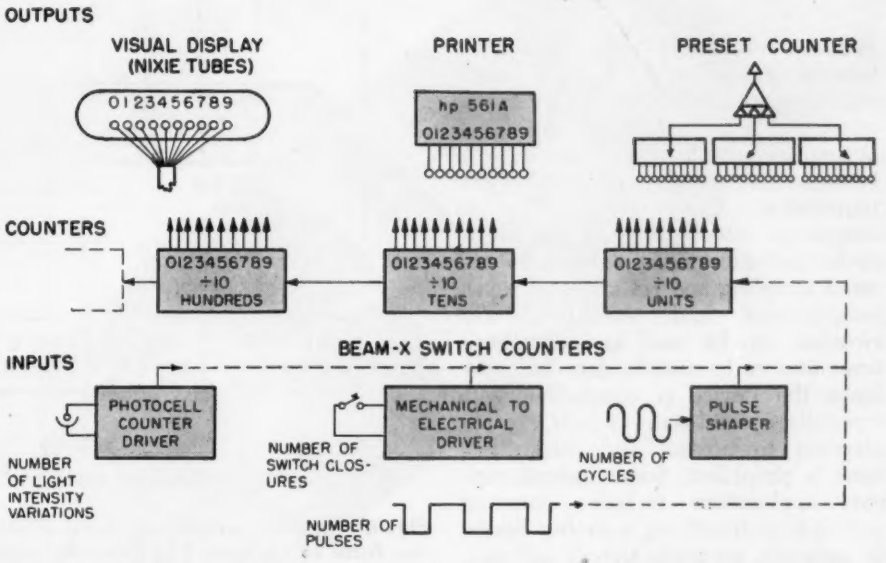

Fig. 4 Decade counting: pulses which can represent photocell outputs, mechanical switch closures or some frequency are delivered to the switching grids of the first Beam-X switch. The tenth output of this switch is used to advance the succeeding switch one position. Thus, wih two Beam-X switches, 99 counts can be accumulated and, with three, 999 and so on indefinitely. In addition to the cascade or "carry" output, current is available at each of the ten positions to activate visual readouts, show the progress of the count, activate a printer for recording information upon command, or to perform useful work at the end of a preset number of events.

BASIC FUNCTIONS AND APPLICATIONS

The manner in which the Beam-X can be combined with other components to perform the basic functions of decade counting, multiposition distribution and data converting is illustrated in the block diagrams of Figs. 4, 5, and 6.

Here is a brief outline of some of the ways these functions can be applied in several fields.

Electronic instrumentation: The natural counting ability, low cost and the fact that the device alone performs the entire counting function as compared to the four vacuum tube or eight transistor circuits which it replaces, makes the Beam-X switch a basic component for frequency, period and occurrences measuring equipment. The switch can be used in digital voltmeters to count and display the decimal equivalent of the unknown voltage directly on electronic Nixie indicator tubes. Multiplexing instruments could display many waveforms on a single gun oscilloscope with the Beam-X switch's outputs sampling and gating wave forms to the scope by use of time division multiplexing. Word generators will use the switch's ability to supply variable length pulse groups for test equipment applications and sampling instruments can employ its memory feature to store high speed information for recording on slower equipment.

Aircraft, Missiles and Space Technology: Due to its inherent reliability, rug-

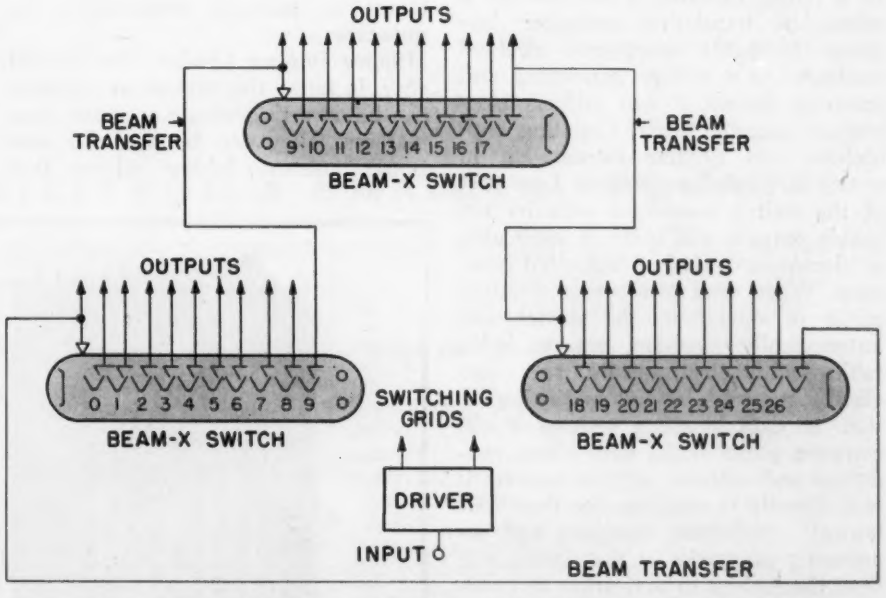

Fig. 5 Multiposition electron distribution: this mode of operation is designed to utilize the individual outputs of the Beam-X switch to perform multiposition functions sequentially. Only nine positions of each switch are provided with the tenth output being used to transfer the electron beam from switch to switch. Driving pulses are delivered to all tubes in parallel so that synchronous operation is assured. Nine constant current outputs per switch can be used for multichannel commutating in gating, timing or sampling applications such as airborne telemetry.

gedness and ability to withstand extreme temperatures, the Beam-X switch will find wide application in aircraft and missiles. For flight line test and check out equipment, the switch can be used in tachometers and as a multiposition sequencing device. Its ability to sample at rates exceeding ten megacycles indicates its application to test stand sampling and recording of stress, temperatures and the like. The switches can be used as multiplexing commutators to sample data in flight. Since the device is compatible with low-voltage solid-state circuits, its application to present and future systems is simplified. Some ground support applications include: counting and display functions; a timing device to generate accurate signals for calibration; and a counter in angle encoding systems.

Computers, Data Processing and Control Systems: The Beam-X switch has unique properties of data conversion as was shown in Fig. 6. These features can be used to perform binary coded decimal to decimal conversion or the switch's outputs can be used to generate step functions of voltage. As a binary decoder, it can provide a means of translating computer language to easily recognized decimal readouts. As a voltage generating and scanning device, it can address electrostatic storage tubes. Counting capabilities can digitize information in analog to digital converters. Low cost of the switch combined with its ten usable outputs will make it applicable in electronic control of industrial processes. When used in a preset counting mode of operation, the device can automatically position rotary index tables and electronically sort and classify material for automatic inspection. In data handling systems it can compare preset limits with actual conditions and activate printers and readouts directly to establish the time "off-normal" conditions. Scanning and sequencing properties of the device will lend themselves to activation of crossbar switches or electronic multiplexing for process control application.

Communications: Due to the switch's high speed capabilities no information is lost and cross talk is eliminated in multiplexing many conversations over a single telephone pair. Because of its ability to perform both parallel to serial and serial to parallel conversion, the device can be used to both commutate and decommutate the information. Teletype messages can be encoded by the switches addressing the column and rows of a resistive matrix. Decoding can be accomplished by using the switch in a sequencing mode of operation. Frequency synthesizers can employ Beam-X switches to divide a known frequency by a variable factor to generate controllable frequencies.

Military Systems (Radar, Fire Control, etc.): In radar, the devices, as counters, can be used to generate accurate range markers. They can be used for electronic antenna lobing where their ability to perform as a reversible scanner will apply. Ability to generate controllable output voltages indicates the use of the device as the heart of servo controlled antenna positioning systems.

With a life expectancy of over 50,000 hours and with extremely rugged construction to overcome severest environmental conditions plus great versatility, the new Beam-X switch is a unique tool in the hands of the design engineer.

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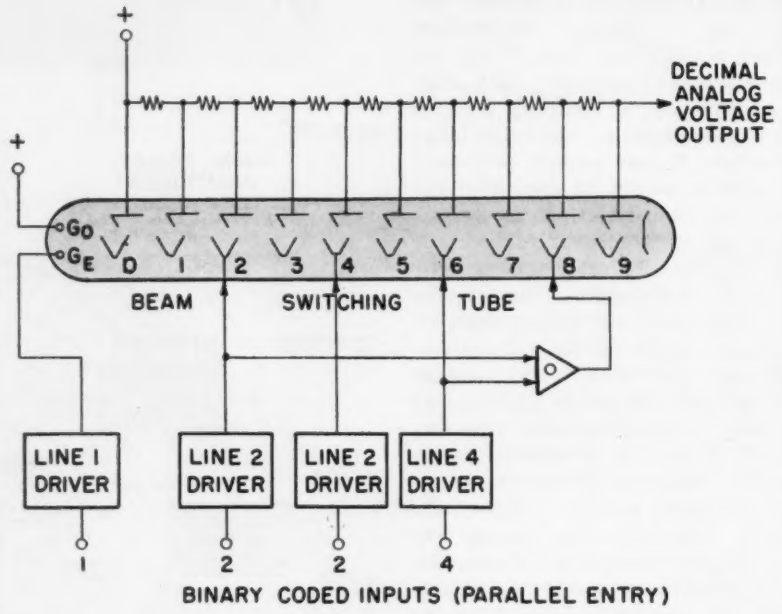
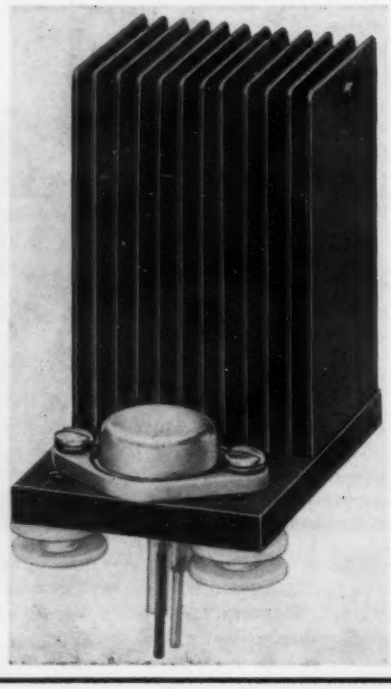


Fig. 6 In data processing, there is a need to convert information rapidly from one form to another. The Beam-X switch can handle this job by accepting binary coded decimal instructions and producing either the decimal or analog equivalent as a useful output. This technique is used in air traffic control systems to display the decimal equivalent of a plane's binary identification number.



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A new series of semiconductor radiators can dissipate from 5 watts to 100 watts when used with forced convection. Models are available for use with rectifiers, zener diodes, and transistors. With forced convection applied to the R-5030, for example, a transistor nominally rated by its manufacturer at 10 watts may be conservatively operated at 30 watts. The R-5000 Series is available in copper or aluminum. A surface machine flat to within 0.0002" is provided for mounting the semiconductors: transistors, rectifiers or zener diodes. Screw holes for mounting any semiconductor type can be provided. Plastic shoulder washers are furnished for insulating the heat sink from its mounting. Curves of thermal resistance at various airflow rates and ambient temperatures will be supplied for specific semiconductor requirements. Wakefield Engineering, Inc., Wakefield, Mass.

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AMPLISOLVER*

*American Electronics' new Amplifier/Resolver module

GREATER STABILITY IN A SMALLER PACKAGE!

AMPLISOLVER is a compact package only 3 inches long, with a Size 8 winding compensated resolver and a dual channel buffer amplifier, within a Size 15 frame. AMPLISOLVER offers unity transformation ratio with Zero phase shift, over a temperature range from —55°C to +125°C.

AMPLISOLVER is the lightest module of such accuracy in the industry, weighing only 8 oz. The unit features an input impedance of 1 megohm minimum with a low output impedance of 270 + j400 ohms. Direct drive from resolver to amplifier eliminates the cable connections. Trim adjustment on AMPLISOLVER can be made in the field to ± 2% of unity transformation ratio of 1 to 1. Its versatile design features permit adapting AMPLISOLVER to computing resolver chain functions.

SPECIFICATIONS—MODEL 15RA5E-11D

Input Voltage	10
Amplifier Power Supply (Volts D.C.) (Reg.)	30 ± .3
Input Impedance	1 megohm min.
Output Impedance (ohms)	270 + j400
Maximum Null Voltage (volts)	
Fundamental	.010
Total	.015
Maximum Functional Error (%)	0.1
Transformation Ratio (Rotor/Input)	1.000 ± .001
Phase Shift (Degrees)	0 ± 0.1
Meets MIL SPEC MIL-E-5272C	

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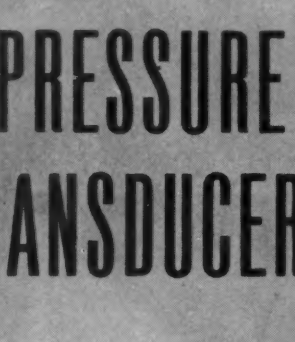

Model 143

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ULTRASONIC DELAY LINES

Multicomponent Glass Materials Reduce Temperature Dependence

From the inception of solid ultrasonic delay lines during World War II fused quartz and fused silica, which are both vitreous SiO_2 but are differentiated because of their different origins, have been employed almost exclusively as the wave propagation media for ultrasonic delay lines operating at 10 megacycles and above. Not only does fused silica exhibit the homogeneity and isotropy required for high frequency operation, but it has extremely low acoustic attenuation as well. The acoustic attenuation figure used in delay line work is 0.1 to 0.2 x 10^{-8} decibels/microsecond/megacycle.

On the negative side, however, the time delay and acoustical attenuation of fused silica are appreciably temperature dependent. Weston H. Jenkins of Corning Glass Works, Corning, N. Y. reports that for shear waves in fused silica, the time delay–temperature coefficient is –80PPM/°C and the acoustical attenuation–temperature coefficient is –5 to –10%/°C.

Because of this temperature dependence, he says, delay lines for precise applications must be packaged in temperature-controlled cases. Although the auxiliary parts and power thus required are relatively minor matters when delay lines of several thousand microseconds length are under consideration, Jenkins points out that the magnitude of these requirements becomes disproportionately great for short delay lines of a few tens or hundreds of microseconds, particularly those which are to be used for airborne applications.

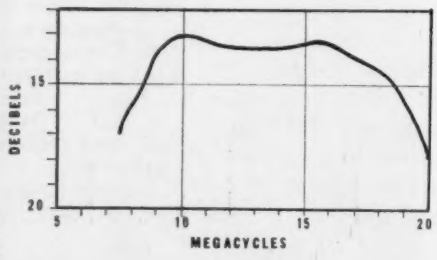

Fig. 1 Temperature dependence of insertion loss for a 2000 microsecond, 30 megacycle fused silica delay line, referred to attenuation at room temperature. Taken from A. H. Meitzler, "Temperature and Frequency dependence of Insertion Loss In Delay Lines," 1958 IRE National Convention Record, Part II.

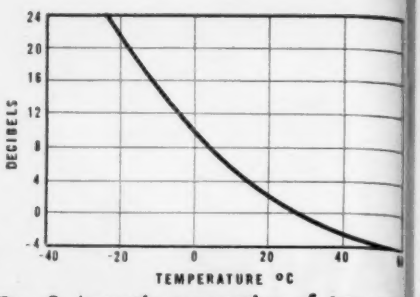

Fig. 2 Acoustic properties of two new delay line glasses developed by Corning Glass Works.

	Glass A	Glass B
Shear Wave Velocity, CM/μ SEC	0.282±.001	0.283±.00
Time Delay— Temperature Coefficient, PPM/°C	+7.5±1	−0.5±
Acoustic Attenuation, DB/μSEC/MC	4.5±0.5x10^{-3}	5.5±0.5x10^{-}
Acoustic Attenuation— Temperature Coefficient %/°C	−0.5±0.3	−0.5±0.

Fig. 3 Insertion loss as a function of frequency for a short ultrasonic delay line of Glass A. Transducer capacitance tuned out at only a single frequency.

The general problem of materials for delay lines has long been pursued. The search has concentrated on glasses rather than other materials for delay lines operating at 10 megacycles and above. Jenkins says this interest in glasses is well founded. To avoid acoustic loss by scattering, ordinary materials of crystalline structure must be avoided. This eliminates metals, for example. Organic materials are very high in attenuation. This eliminates plastics. Large single crystals have been mentioned as possibly having low acoustic attenuation. But they would be unlikely to allow multiple traverse of the delay line blank by the ultrasonic beam because of the directional characteristics of the crystal's elastic properties. Hence, he says, for general high frequency delay line use, only glasses are left. However, according to Jenkins commercial glasses have always been designed for properties other than acoustic. As a result none with characteristics particularly good for delay line use have been found.

Recognizing that work on special glass compositions was needed, Corning Glass Works began a program in the fall of 1958 to develop glasses with low time delay-temperature coefficient specifically for delay line use. This program, currently in progress

consists of systematic composing and laboratory melting of glasses for acoustic tests. By employing precise time-delay measuring equipment they have been able to obtain satisfactorily accurate results on small samples, which they say is most helpful when melting is done on a laboratory scale.

Information gained on the relationships of glass composition and acoustic properties is used in the formulation of subsequent compositions. Also, melts of the most promising glasses are repeated several time to check variations that might be encountered in production runs in a platinum optical-glass tank. These variations have been negligibly small.

Figure 2 tabulates the acoustic properties of the two best glasses so far developed. Time delay-temperature coefficient has been brought into close control at a very acceptable level. Acoustic attenuation in multicomponent glasses, however, appears to bottom out in the region of 5×10^{-3} db/microsecond/megacycle. But the acoustic attenuation–temperature coefficient is about one-tenth that for fused silica, and the shear wave velocity is ¾ that of fused silica (0.376 cm/microsecond), thus permitting delay line size reduction.

Figure 3 is a plot of insertion loss vs. frequency for a 36 microsecond line of glass A operating into an eight-ohm load. This line employs ferroelectric ceramic transducers operating in the shear mode.

Efforts to develop delay line glasses of lower acoustic attenuation without sacrificing the other desirable properties that have been obtained are being actively continued. Jenkins believes, however, that the types described here, which are being used in delay line production, will go far in eliminating the problems associated with fused silica.

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MASER AMPLIFIERS

New Techniques Reduce Noise Temperatures to Less Than 10°K

Several recent advances in maser technology made at the Hughes research laboratories have contributed to the practicability of masers for system applications. The large electromagnet of most previous masers has been replaced with a small permanent magnet. The discovery of ferrites and garnets suitable for use at very low temperatures has made possible the development of liquid-helium-cooled circulators. Thus the noise contributed by the circulator has been reduced from about 20° Kelvin to a small fraction of a degree.

Hughes scientists said that amplifier noise temperatures of less than 10° Kelvin are now possible in the 1-to-15 KMc band for amplifiers having gains and bandwidths typically between 20 and 30 db and 5 to 30 Mc, respectively. Thus it is possible, they said, to achieve overall receiver noise temperatures, not including the noise output of the antenna, of 10° Kelvin. This contrasts with the value of 1500° Kelvin for the noise temperature of a good conventional receiver having an 8 db noise figure.

An important advance is the development of multiple-cavity masers in which each cavity consists of a silver-plated ruby crystal. The operation of this type of amplifier is analogous to that of a synchronously tuned multiple-cavity filter having a power gain in each section. The addition of a second cavity to a conventional single-cavity maser increases the bandwidth from 5 Mc to 18 Mc when the overall gain is adjusted to 26 db in each case. A third cavity provides a small additional improvement, as is expected from the theory for the behavior of such circuits.

Another problem that had to be solved in order to make maser amplifiers practical for systems such as radars was the development of a means for protecting the receiver during the transmission of strong signals from nearby antennas. It is necessary to prevent signals of greater than about one microwatt of peak power from arriving at the input to the maser because these signals reduce the gain of the maser for a large fraction of a second. The protection of the maser had to be accomplished without degrading its noise temperature—a serious problem in view of the fact that a device ahead of the maser having a loss of 0.
db, and operating at room temperatur
produces a noise temperature of abou
35° Kelvin, which adds directly to th
maser noise. The problem was solve
in two ways, both of which use th
operation of ferrite devices in th
liquid-helium bath of the maser. Th
first method involves use of a simpl
two-port transmission device whic
contains a ferrite element in a d
magnetic field, the magnitude of whic
can be set at either of two levels b
switching. In one state the device tran
mits with an insertion loss of a fe
tenths of a db; in the other state
reflects the input power so that th
output is down 30 db. This device pr
vided adequate protection for a mas
amplifier which was operated in a co
ventional X-band airborne fire contr
radar with a common transmit and r
ceiver antenna. The magnetic circu
of the ferrite switch is pulsed in sy
chronism with the transmitter pulse.

A cooled circulator especially d
signed so that the magnetic field c
be reversed rapidly provided a secon
solution. The input signal to the r
ceiver is switched from the maser t
a matched load at another terminal
the circulator. This is accomplishe
without degrading the noise temper
ture of the maser.

Another important advance co
tributed by one of Hughes' basic r
search programs in masers is the u
derstanding of the principles an
limitations of the design of ruby mase
for operation at higher temperatur
than those associated with liqu
helium. This work resulted in the r
cent demonstration of useful mas
gain at liquid-nitrogen temperatu
which is 77°K. An X-band amplifi
having a noise temperature of 100°
was obtained with a greatly simplifi
cryogenic system. For applications
the lower frequencies, noise temper
tures considerably lower than the ba
temperature are feasible. This sugges
the use of closed neon (27°K) or h
drogen (20°K) cooling systems, wi
resultant simplifications of cryoge
apparatus. It now appears that prac
cal, continuously operating, clos
cryogenic systems for use with any o
of several refrigerants will be availabl

These advances, together with oth
that may follow from the continui
work on masers at a number of labor
tories throughout the country, m
have made maser techniques availab
for advanced applications to syste
which require very low noise receive

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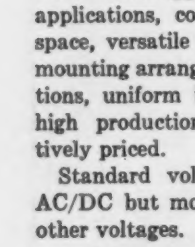

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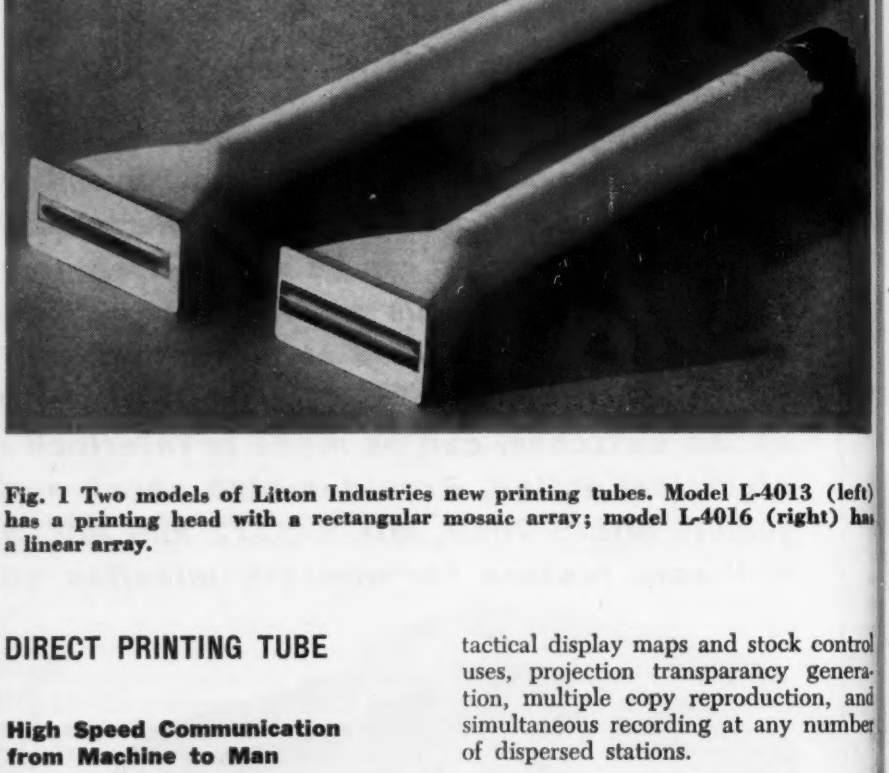


Fig. 1 Two models of Litton Industries new printing tubes. Model L-4013 (left) has a printing head with a rectangular mosaic array; model L-4016 (right) has a linear array.

DIRECT PRINTING TUBE

High Speed Communication from Machine to Man

Developments of a high definition electron gun and a unique metallic-element mosaic printing head have led to a new direct electronic printing tube. Litton Industries, San Carlos, Cal. predicts that it could provide the much needed high speed, machine-to-man coupling for modern computers and advanced data handling equipment.

The new cathode ray tube, tradenamed, Printapix, is already being incorporated in facsimile, oscillography, address labeling and television type image reproduction equipment. Other applications soon will include high speed computer readout, controlled information storage and erase for military tactical display maps and stock control uses, projection transparancy generation, multiple copy reproduction, and simultaneous recording at any number of dispersed stations.

OPERATION AND DESIGN

Litton's direct printing tubes employ a metallic element mosaic target or printing head in place of the phosphor screen usually found in cathode ray tubes. Type L-4013 provides a printing or writing head 0.15 inches high to accommodate writing of complete characters or symbols across the entire head width. This rectangular head may also be used for sequential scan line (TV type) operation. Use of this tube minimizes system requirements for set-up and operation. L-4016 model has a uni-dimensional conductive element array for sequential scan line operation.

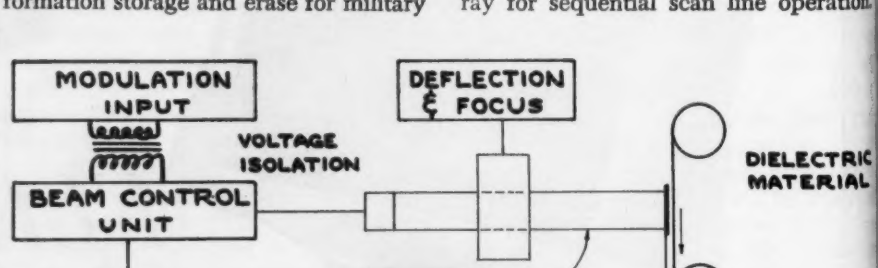


Fig. 3 Operation block diagram using direct writing tube.

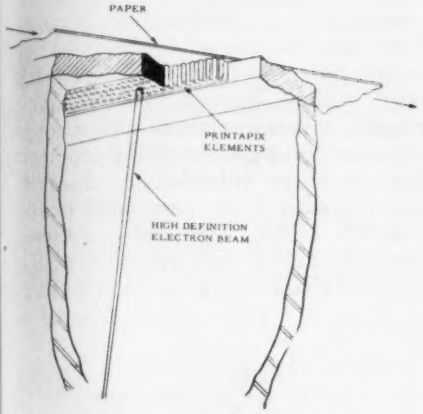


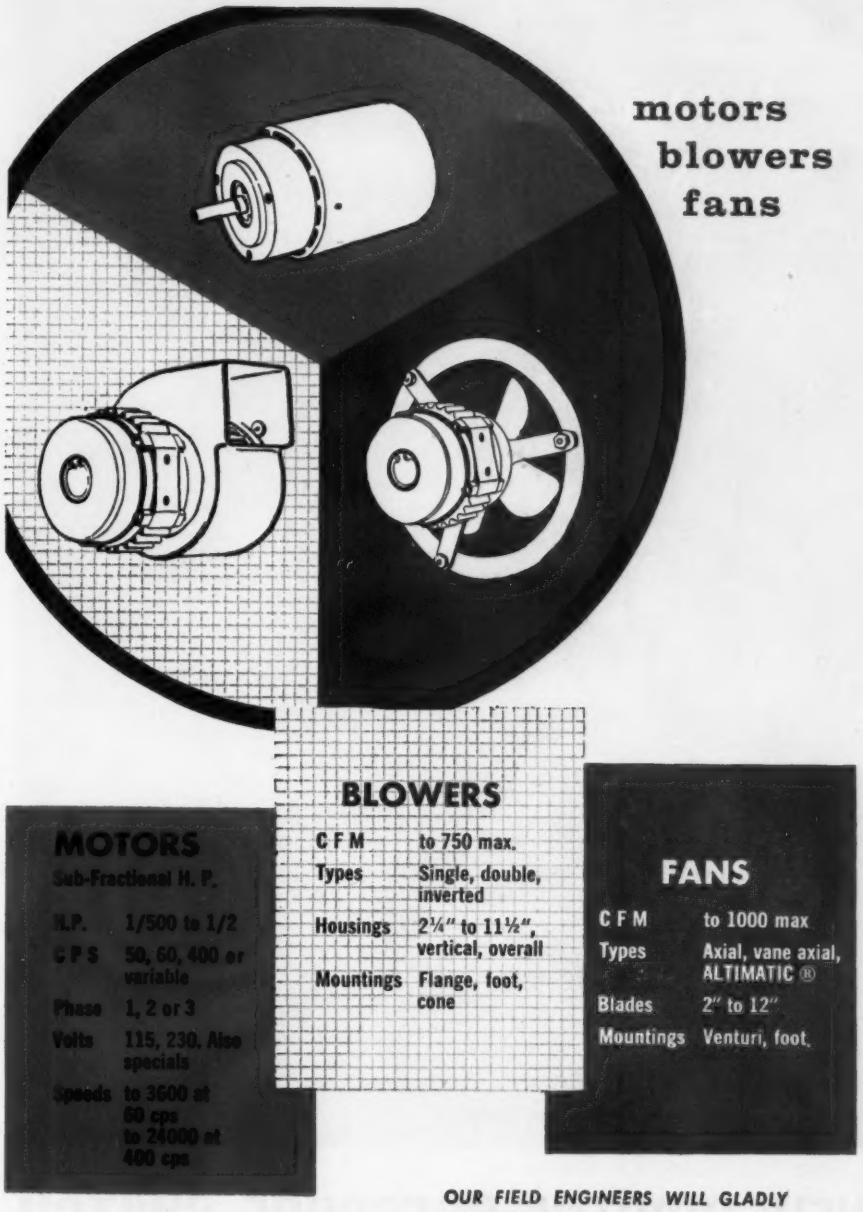
Fig. 2 Working characteristics of Litton's direct printing tube (Model with the rectangular mosaic head). Ordinary or glossy surface paper provides a low cost base material for image rendition. Printing quality can be improved by rendering the opposite side of the paper slightly conductive. Various transparent media, such as glass and thin transparent plastic or commercial sheet polyesters, may be used with Printapix. Dielectric material transport requirements depend on the proposed application.

Fig. 1 is a general view of the two models.

Both tube types provide a full 2.75 inch wide writing capability. Metallic elements are 0.001 inch diameter on approximately 0.004 inch centers, providing an element density of 62,500 conductors per square inch. Tubes with much closer spacing of writing elements can be furnished to accord with application requirements. Element densities up to one million per square inch are feasible.

With either type tube, deflection of the electron beam along the printing head width accomplishes one dimension of motion. The dielectric material is positioned immediately adjacent to the writing head, and movement of this dielectric base material past the tube face provides the orthogonal displacement. Working characteristics of the tube are shown in Fig. 2.

Electrons in a high intensity, high definition beam produce, a charge pattern on a dielectric surface, such as ordinary paper or plastic, through the mosaic printing head. This mosaic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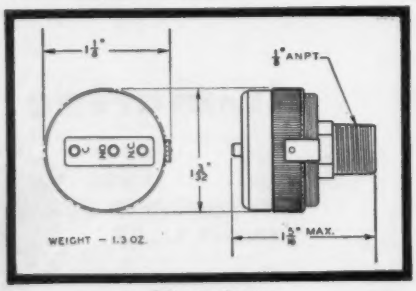

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The developing powder is released as a cloud or fog in close proximity to the charged dielectric surface. Pigmented plastic is attracted to and retained on the charged areas by the coloumb force. Since the resultant image color is determined by the pigment, multicolor reproductions may be obtained by proper development.

Simplicity results from the direct coupling of electrons to non-sensitized base dielectric, without conversion to light and use of optics. High definition is achieved through use of 0.001" diameter conductive elements and electron beam. Writing rates are 0.1 microsecond per element.

An operational block diagram for the tube is shown in Fig. 3. Operating circuitry and components of the Printapix tubes are similar to those normally used for display, readout or oscillographic applications. Ordinary television components and techniques are quite satisfactory in many instances. For operating convenience, the tube is frequently run with the printing head at ground potential.

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WORTH FILING

Synchro and Resolver Manual

A new 25 page handbook presents a detailed account of the application and measurement problems associated with synchros and control resolvers. It covers such topics as: what is a synchro; application problems; electrical zeroing procedures; electrical error measurement methods; null measurement procedures; phase shift and transformation ratio methods.

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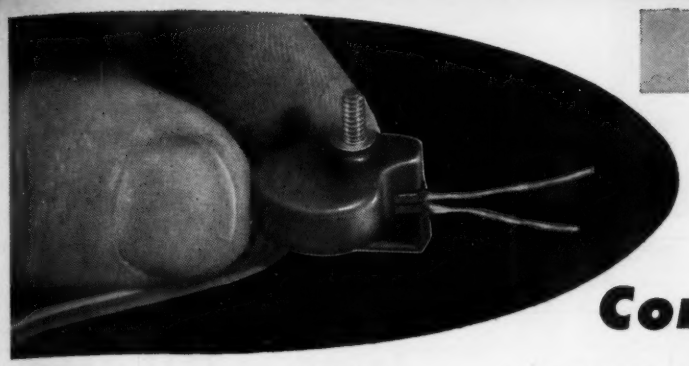

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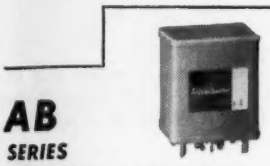
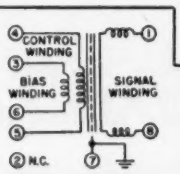
Specification Table below gives data on the 6 standard series of CGS INCREDUCTOR® Controllable Inductors:

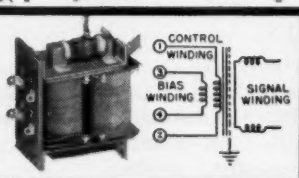
CGS INCREDUCTOR® Controllable Inductors are used for electronic Tuning applications involving: Power, Wide Tuning Range, High Q, Rugged Environmental Conditions. Units available exceeding MIL-T-27A.

INCREDUCTOR® Controllable Inductors: I_c in the control winding causes a change in the permeability of the signal winding core material which causes a corresponding change in the signal winding inductance. A current, I_b, in a separate bias winding is used to set the operating point of the signal winding core on its bh curve. Signal windings can handle powers from about two to eight watts. The insulation test voltage between all electrodes is 1,000 Volts DC, working voltage is 500 Volts DC.





Type	Minimum Operating Frequency	Nominal Maximum Inductance	Maximum Inductance Change Ratio	Signal Winding Capacity to Electrostatic Shield	Maximum Q
AB SERIES 2⅝" × 1 33/64" × 2 5/64"	L_c = 6h max., I_c peak = 50 ma., I_c max. rms = 30 ma., R_c = 1000 ohms, L_b = 175 mh, I_b max = 30 ma., R_b = 200 ohms.				
63AB1	0.7-2.5 mc	100 μh	14:1	15 μμf	140
63AB2	0.3-1.0 mc	500 μh	14:1	30 μμf	140
53AB1	0.1-0.35 mc	2500 μh	14:1	60 μμf	140
AQ SERIES 1 13/16" × 1¾" × 1"	L_c = 3h max., R_c = 200 ohms, I_c peak = 100 ma., I_c (avg.) = 70 ma., L_b = 0.5h, R_b = 200 ohms, I_b max. = 6 ma.				
62AQ2	1.5-5 mc	20 μh	6:1	6 μμf	70
62AQ3	2.5-8 mc	7.7 μh	6:1	5 μμf	70
62AQ4	3.5-10 mc	4.3 μh	6:1	4 μμf	80
72AQ2	7-20 mc	1.2 μh	5:1	4 μμf	80
72AQ3	20-60 mc	0.37 μh	5:1	3 μμf	80
81AQ2	60-150 mc	0.10 μh	3:1	3 μμf	80
DB SERIES 2 5/16" × 1 33/64" × 2 5/64"	L_c = 50h max., R_c = 750 ohms, I_c peak = 130 ma., I_c (avg.) = 70 ma., L_b = 2.5h, R_b = 500 ohms, I_b max. = 525 ma.				
38DB1	0.2-5 Kc	3000 mh	350:1	85 μμf	60
48DB2	1-20 Kc	500 mh	350:1	85 μμf	80
48DB3	2-40 Kc	100 mh	350:1	75 μμf	100
58DB1	4-100 Kc	20 mh	350:1	65 μμf	100
58DB2	10-200 Kc	4 mh	350:1	60 μμf	130
DQ SERIES 1 13/16" × 1¾" × 1"	L_c = 6h max., R_c = 325 ohms, I_c peak = 100 ma., I_c (avg.) = 70 ma., L_b = 1h, R_b = 200 ohms, I_b max. = 10 ma.				
65DQ1	1-5 mc	25 μh	36:1	3 μμf	70
65DQ2	0.7-2.0 mc	100 μh	36:1	6 μμf	100
55DQ1	0.3-1.0 mc	500 μh	36:1	12 μμf	70



Type	Suggested Operating Frequency	Maximum Frequency Change Ratio	Maximum Q	Control Winding		Bias Winding			
				I_c (avg.)	L in Henries	R in Ohms	I_b (avg.)	L in Henries	R in Ohms
AP SERIES 1⅝" × 1 1/16" × 1 9/16"									
81AP1	88-192 mc	2.8:1	100	70 ma	1.5	225	15 ma	1.1	900
81AP2	48-122 mc	3.2:1	100	140 ma	0.58	100	20 ma	2.1	750
81AP3	88-192 mc	2.8:1	100	140 ma	0.58	100	20 ma	2.1	750
81AP4	130-260 mc	2.6:1	100	140 ma	0.64	88	20 ma	2.3	700

XBK SERIES 2½" × 3¼" × 3"

The XBK Series has Center Frequency tuned with a dual 150 μμf variable capacitor. The 6XBK4 (3.7-216mc: 4 bands) and the 6XBK5 (3.0-209mc: 5 bands) data: Available Sweep 3-16mc (Depending on band). L_c = 20h, R_c = 1500 ohms, I_c peak = 30 ma.

61BT1 2 1/32" × 1 3/16" × 1 7/16"

The 61BT1 is a dual unit for FM & AFC applications incorporating an internal heater and thermostat.

L_{c1} = 1.5h, R_{c1} = 230 ohms, I_{c1} = 9-13 ma, L_{c2} = .04h, R_{c2} = 18 ohms, I_{c2} = 2.5 ma.

Heater voltage 27.5 v DC nominal Size: 2⅛" x 1 11/16" x 1 7/16".

Signal winding: Min effective Inductance, 12 μh: External Capacity, 7-45 μμf: Center frequency, 5.1 mc: Max deviation ± 100 kc.

Magnetic Components Div.

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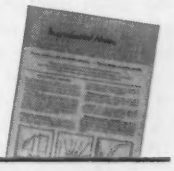
We invite you to write for CGS "INCREDUCTOR® Notes"—28 pages of technical data, charts, diagrams, and applications for Controllable Inductors.



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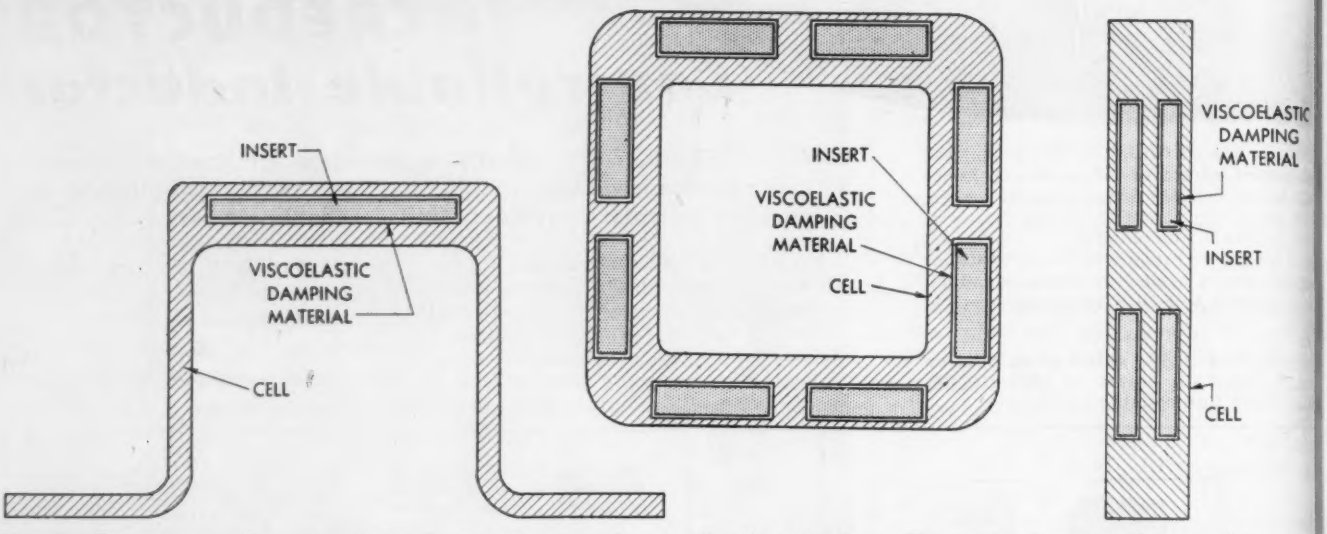


Fig. 4 Resonances of a conventional structure can be damped by the application of a strip damper—a member that dissipates large amounts of energy when attached to a vibrating structure. Two strip dampers above make use of a retainer strip housing an insert. Layer of viscoelastic damping material separates the insert from the retainer

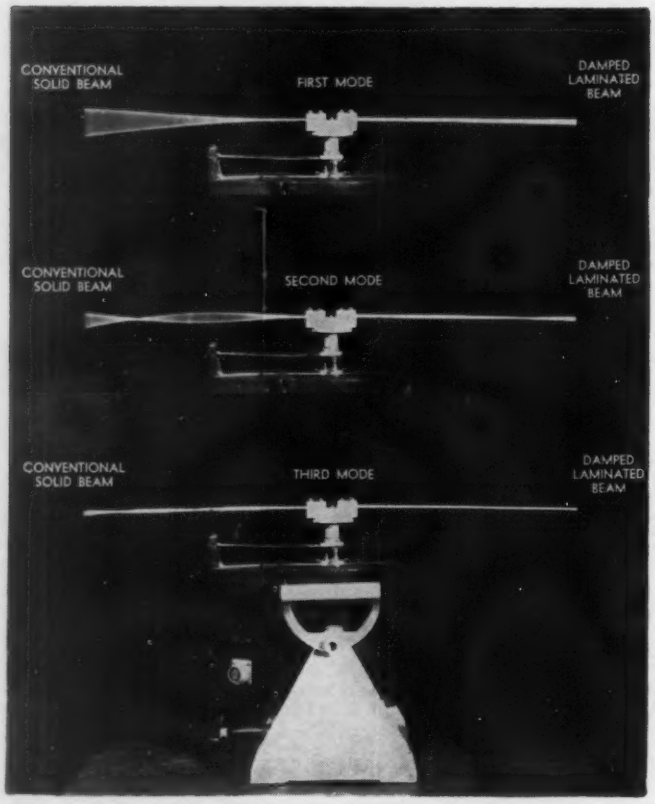


Fig. 1 Top—At a 17-cps sinusoidal vibration input, conventional beam amplifies the vibration by a factor exceeding 100; damped beam amplifies by an approximate factor of 10. Center—At their first harmonic frequency of 105-cps, lower response of the damped beam is striking. Vibration amplification of conventional beam exceeds 100, while that of "Rigidamp" is approximately three. Bottom—At the second harmonic, 300-cps, the damped beam vibrates so little as to appear stationary while the excitation of the undamped member is apparent to the naked eye. Amplification of conventional beam is 50 times that of "Rigidamp" beam.

SYSTEMS PACKAGING

New Design Technique Minimizes Resonant Respons

The control of resonant vibration is important in the design of structures and supports for electronic and electromechanical equipment subjected to environments containing excessive noise, shock and vibration. High vibration and noise levels generated by modern, high-energy power sources exist over a broad frequency range. When the power-source vibration becomes amplified by structural members, large dynamic stresses are created in the structure, transferring high accelerations to critical components within system packages.

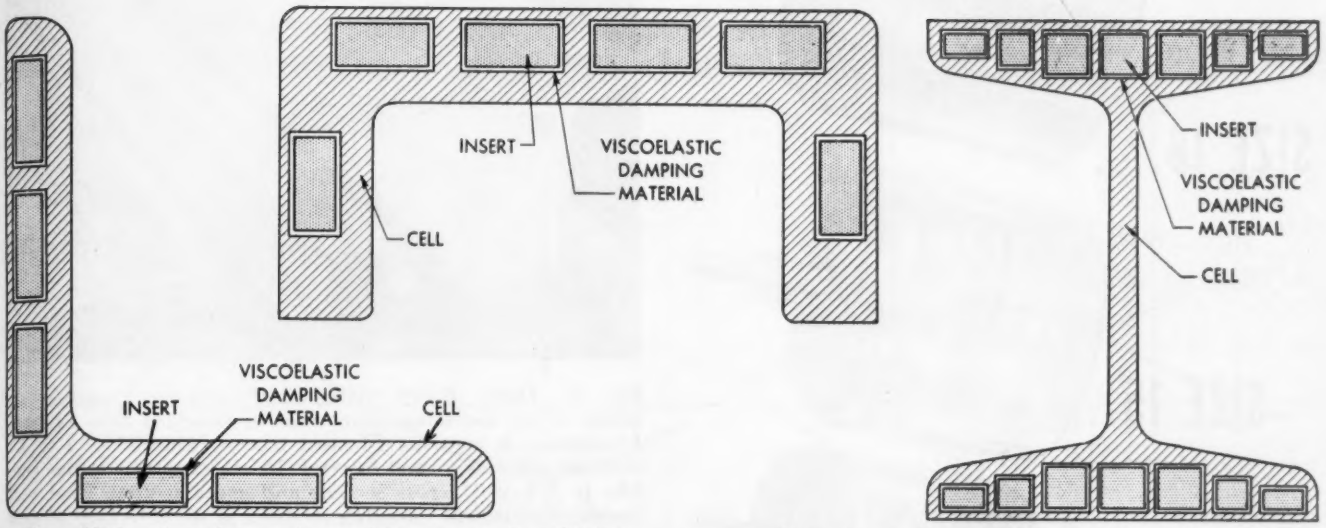
Jerome E. Ruzicka, Barry Controls Staff Engineer pointed out that current design objectives associated with system packages include low noise, light weight, increased reliability and long life at higher operating speeds. Avoidance of detrimental resonance conditions to which these subsystem packages are subjected, according to Ruzicka, usually have taken a number of forms:

- Rigidization of structural members
- Decoupling of resonating systems
- Detuning of coupled resonators
- Using high fatigue-strength structural materials
- Reducing vibration excitation of the structure.

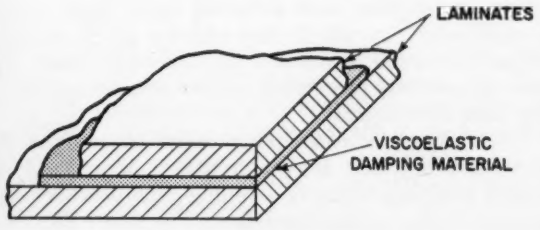
Now, engineers of Barry Controls, Inc., Watertown, Mass., have a new solution to the shock and vibration problems of the space age: vibration-resistant structural members and production assemblies. Barry Controls' approach involves the building of high damping characteristics into the new structural fabrications, achieving greater damping of resonant vibrations without the use of vibration isolators.

CONVENTIONAL VIBRATION DAMPING

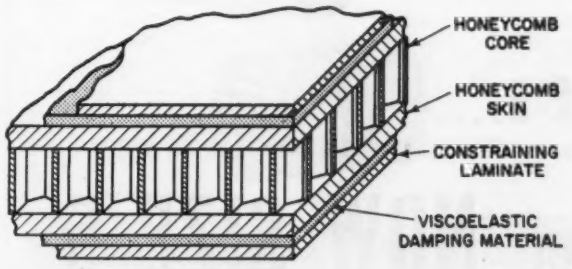
Conventional vibration damping approaches have not been completely adequate in coping with some of the modern problems of structural resonance resulting from the complex



walls; additional retainer strips and inserts can be added to the strip damper design (lower illustration) thus providing a convenient means of varying the amount of damping supplied to conventionally designed structure.

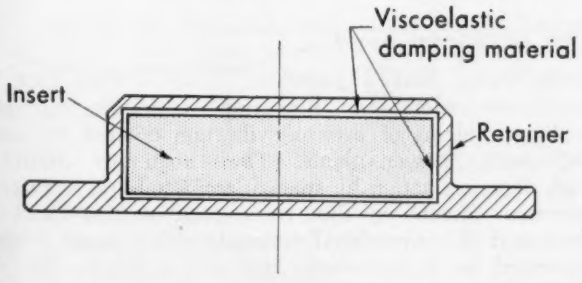


VISCOELASTIC-DAMPED LAMINATED SHEET



VISCOELASTIC-DAMPED HONEYCOMB SHEET

Fig. 2 Large-area sheet members, such as panels or plates, are susceptible to noise transmitted through the atmosphere, as well as mechanically transmitted forces and motions. Resonant amplification of conventional sheet metal chassis fabrications can cause electronic components failures. In the above designs of damped structural sheet, the damped laminated sheet contains two laminates separated by a uniform layer of viscoelastic damping material. The damped honeycomb sheet fabrication contains a standard honeycomb section (core plus bonded skin members) to which a constrained layer of viscoelastic damping material has been added. Laminates in both of these designs carry loads. When the damped-sheet designs undergo flexural vibrations, the viscoelastic damping layer is subjected to a cyclic shear strain that dissipates energy. Energy dissipated by the damped fabrications is a function of the design geometry and the physical properties of the damping material. Some applications require more than two laminates in the damped laminated sheet while other applications derive adequate damping properties with a constrained damping layer added only to one side of the honeycomb sheet.



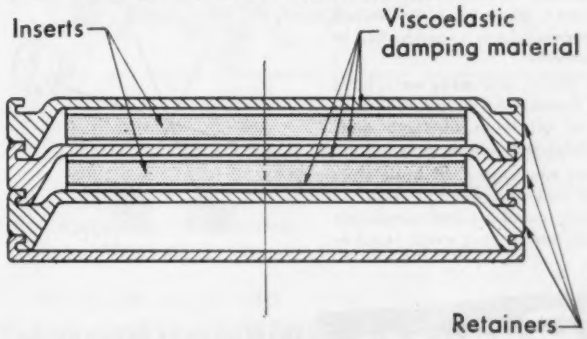
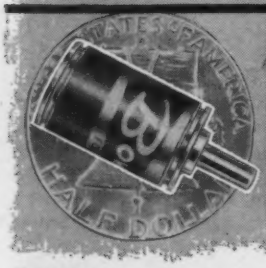


Fig. 3 Cell-insert design technique of damping structural beams produces a viscoelastic-shear damping mechanism integral with load carrying members. The large number of inserts shown in the structural shapes are to develop high damping for all bending vibration modes as well as torsional vibrations of the beam. Also, multiplicity of inserts decreases the possibility that a fabrication device (bolt or rivet) prevents gross shear from developing in the viscoelastic damping layer during vibration.

AND NOW SIZE 5



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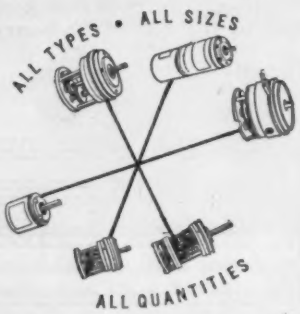

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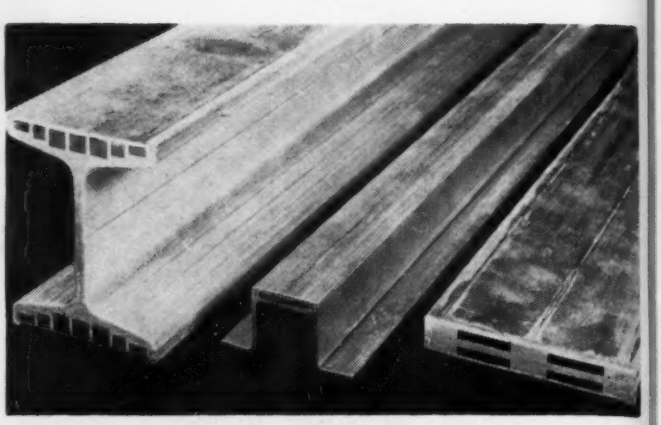

Fig. 5 Three Barry "Rigidamp" structural members; beam at left has same dimensions as standard 3-in. I-beam. Aluminum, it contains 14 steel inserts. Aluminum 1 x 1" channel contains a steel insert 1/16" thick. Rectangular section is 1/2 x 3" cross section and contains four steel cell inserts. Viscoelastic damping medium at the interface of cell and insert absorbs dynamic energy when the beams flex under impressed vibration.

nature of dynamic environments. Designs involving rigidization, decoupling and detuning have been unacceptable in applications in which they add too much weight. In addition, increased structural stiffness may react with local mass properties, producing a new resonance more damaging than the original.

Decoupling decreases the number of coupled resonators that exist between the environment input and the component position, whereas detuning separates the natural frequency of the components from the structural natural frequencies on predominant excitation frequencies. However, natural resonances of structures and components can still be excited because the frequency range of mechanical and acoustic random excitation existing in modern dynamic environments is sufficiently broad to encompass many of the natural frequencies of the structure.

Design approaches that use high fatigue-strength structural materials rely on fatigue, damping and elastic properties of engineering materials and are still in the developmental stage. Vibration isolators have been effective in reducing vibration transmitted to a structure; however, because structure vibrations may still be increased to unacceptable levels, vibration isolators may not be the solution to a specific problem.

NEW APPROACH

Ervin Pietz, Barry's President, believes that their new structures—trademarked "Rigidamp"—will solve many of the vexing problems of extreme vibration created by modern high-energy power plants. These materials attain their high damping action by special laminated and cellular construction. Sheets on thin rectangular section beams are laminated of conventional materials, either metal or plastic, separated by a viscoelastic damping medium. In flexing under the impressed vibration, the separate laminations of structural materials slide relative to each other. The sliding is impeded by the specially formulated viscoelastic material and most of the energy of resonance is absorbed in straining and the viscoelastic layer in shear.

New Ketay size 15 integrating motor tachometer —

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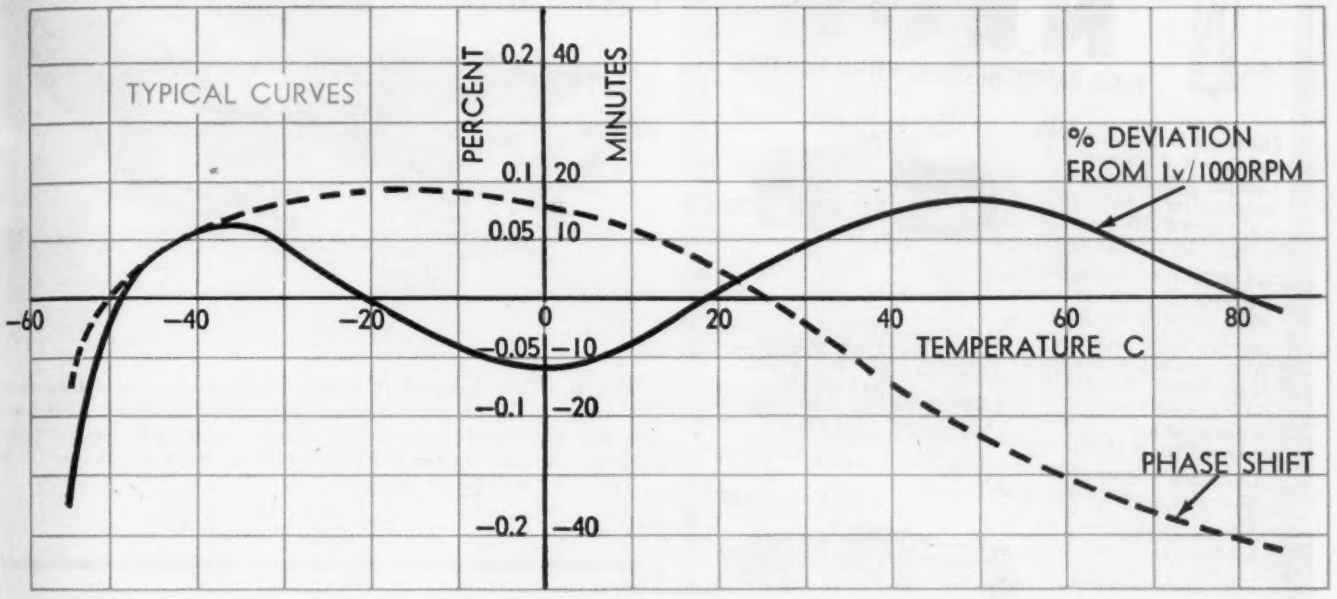
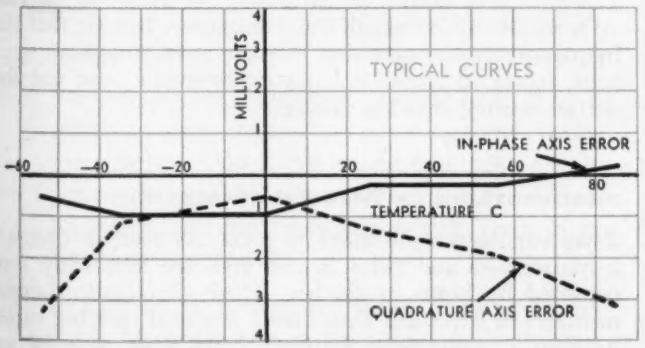
- **USES NO HEATERS**
- **HAS 1.0000 VOLT PER 1000 RPM OUTPUT GRADIENT OVER ENTIRE TEMPERATURE RANGE**



The Ketay integrating motor tachometer, Type 105P2Y has many features that assure high output-to-null voltage ratios and extreme accuracy over the entire temperature range of −55°C. to +80°C.

In addition, the Type 105P2Y will give instantaneous response, for no warm-up time is required at any temperature within the operating range. The Ketay design uses no heating elements, mechanical thermostats, amplifiers or external heat sources and, as a result, the unit has increased life, less weight and less power drain on the over-all system.

The unit will pass military environmental specifications called out in MIL-S-17806.



CHECK THESE GENERATOR SPECIFICATIONS:

Excitation (volts)	115
Frequency (cps)	400
Input current (nominal) amps	0.0275
Input power (nominal) watts	1.9
Output gradient per 1,000 RPM @ 25°C.	1.0000 ± .05%
Phase shift with respect to input at 3600 RPM @ 25°C.	0° ± 10′
Null voltage at 25°C. (Maximum Values)	
IN-phase Fundamental at zero speed	2MV
Quadrature Fundamental at zero speed	6MV
Total harmonic	10MV(RMS)
IN-phase axis error	1MV
Quadrature axis error	1MV
Linearity — 0 to 4000 RPM (percentage of voltage output at 3600 RPM)	± .06%
Variation in output gradient with variation in ambient temperature (−55°C. to +80°C.)	± 0.2%
Variation in axis error with variation in ambient temperature (−55°C. to +80°C.)	± 7MV ± J8MV
Variation in phase shift with variation in ambient temperature (−55°C. to +80°C.)	± 1°
Warm-up time	None
Total unit weight (motor and generator)	15 oz.

Write for detailed specifications and drawings, or for information on other Ketay integrating and damping tachometers.

KETAY DEPARTMENT

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NEW Series mounts from *FRONT* of panel in 15/32" clearance hole (supplements 17/32" Series). Also—units for mounting from *BACK* of panel in 15/32" clearance hole. Unique lenses in 5 colors; give all-angle visibility. Units are fully insulated; meet applicable Mil. Specs.

Ask for Brochures L-159B and L-162.

(Illust. approx. actual size)

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(Front mtg., 17/32")

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(Back mtg., 15/32")

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2-TERMINAL and 1-TERMINAL TYPES

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Ask for Brochures L-156C thru 159B, and L-162.

(Front mtg., 15/32")

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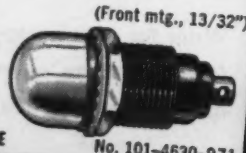

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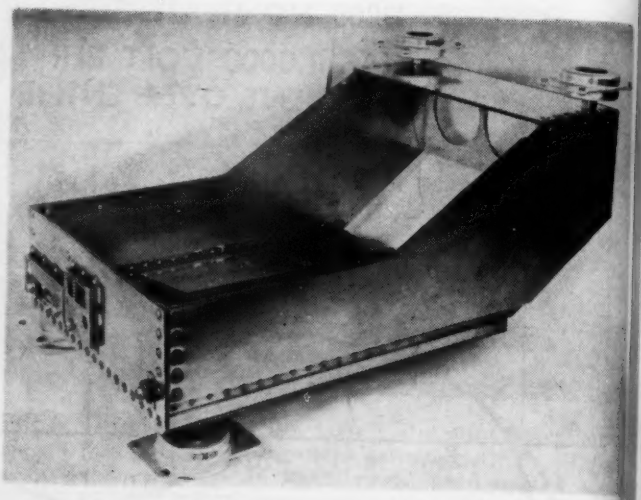

Fig. 6 This damped structure supports a countermeasure system in a high performance Navy aircraft. Damped honeycomb construction provides a high strength to weight ratio with minimal elastic body resonances. Rack measures 27 x 18 x 16", weighs 20 lbs.

APPLICATIONS

Barry engineers believe that the most obvious possible applications of their new structure are: electronic circuit boards, electronic chassis, shelves, dust covers, aircraft parts, test fixtures, missile skins, relays and other parts. Though most of their research to date has been with metal structures, they have made successful applications with structural plastics.

In addition to reducing accelerations transmitted to sensitive components, Barry engineers believe that their structures can provide other significant advantages. Fatigue life is expected to be extended due to the reduction in the ambient stress level of the material. In addition, the structures are not sensitive to changes in vibration input and operate satisfactorily across a wide range of frequencies. The structures exhibit an extremely flat vibration response up to 2,000 cps, although Barry engineers believe that this frequency can be exceeded in most cases. In these situations, increased vibration input requirements need not render an existing structure obsolete.

DISADVANTAGES OF THE NEW APPROACH

Barry engineers were quick to point out that all design is a compromise and gains in one area are frequently compensated by losses in another. Their viscoelastic damped members or structures have lightly less load carrying capacity than a conventional member of the same material and cross section. For identical stiffness, structural damping imposes a slight increase in weight. For identical cross section, the member carries less load. Because many designs are based on dynamic stress levels, they believe that the "Rigidamp" designs may not require an increase in weight or cross section, thus dispensing with some of the disadvantages.

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Edison Servo Motor-Generators are available with any type or size gear head or gear train.

Unlike ordinary "off-the-shelf" components, Edison Servo Motor-Generators are designed specifically to operate as part of an electro-mechanical system.

For example, their motor sections are built to have minimum time constants and reversing times. To insure precise coupling with mating gear trains, output pinions are fabricated *to better than AGMA standards.* Damping constants, from unit to unit, are held to very close tolerances.

In addition to these special system features, Edison Servo Motor-Generators are made to the highest quality standards. They outperform MIL-S-17087 (for motors) and MIL-S-17806 (for generators).

Edison engineers provide you with the exact servo motor-generator your system calls for—not a cataloged component that will only approximate your needs. For this reason, they will work closely with you in developing components that will assure you of the best system performance.

For additional information on Edison Servo Motors, Motor-Generators and other rotary components, write for Catalog 3044.

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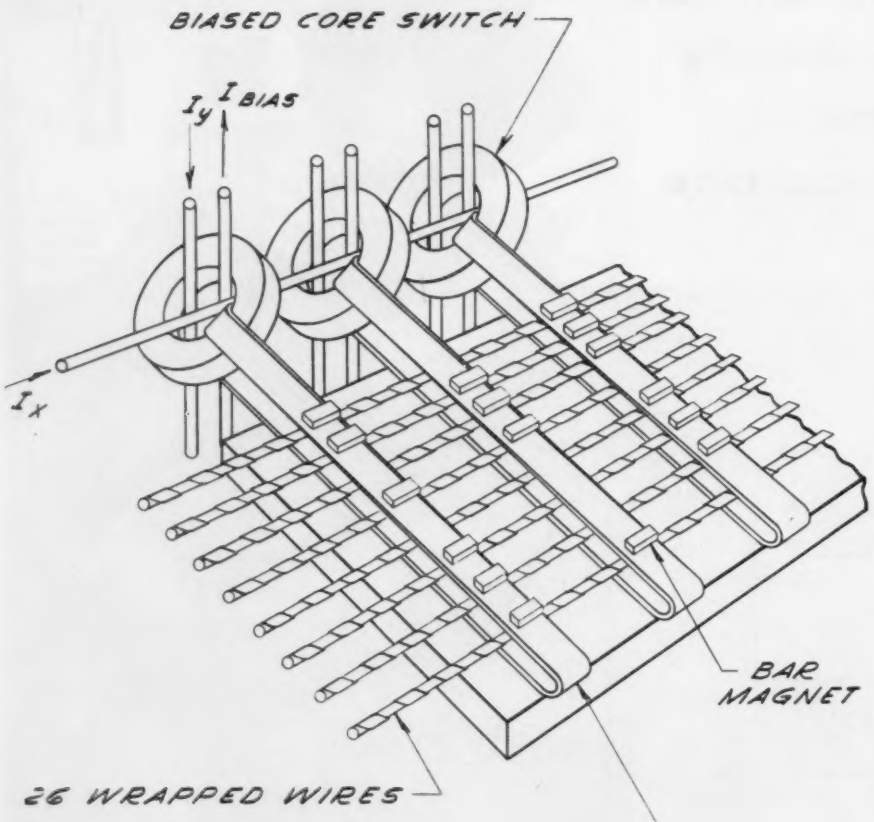

A section of a Twistor-magnet memo frame. Three cores of the biased c switch or transformer and their wo coils or solenoids are shown, with eig intersection twistors. The bar magne are shown as tiny "blocks" on the wo coils. (For reasons of simplicity, t plastic tapes supporting the Twist wires and the word coils have be e'iminated in this drawing, as has t plastic card carrying the bar magnet

PERMANENT MAGNET MEMORY

Memory Cards Store Data by Pattern of Bar Magnets In Photoetched Array

Hair-thin wires wrapped with magnetic metal tape in barber-pole fashion plus tiny bar magnets are the basic elements of a permanent electronic memory that is comparatively inexpensive, easy to produce, and will help speed up computer developments. The memory will supply bits of information at speeds in millionths of a second to a computer.

The permanent memory is the result of a pair of technical achievements: the conception of a memory based on the inhibiting action of a permanent magnet on the magnetic characteristics of a Twistor formulated by Bell Telephone Laboratories researchers; and the development of mass production facilities for memory units by Western Electric Company in fourteen months. Automatic manufacturing techniques achieve efficient production.

MEMORY MODULES

The memory module is built up of arrays of tiny permanent bar magnets located on plastic cards which are superimposed on a Twistor - conductor grid sensing element. The bar magnets are formed by first bonding a 0.001 inch-thick sheet of Vicalloy I, a magnetic material, to a plastic card. The card is then subjected to a high-precision photoetching process to eliminate all the magnetic material except the small bars left at specifically desired locations. The tolerances required for this photo-etching process are far narrower than those needed in standard photoetching work.

SENSING ELEMENT

The sensing element for these magnets is an underlying grid of horizontal a vertical conductors. The wires runni in one direction are magnetic and a called Twistors while those in the p pendicular direction are current c ductors. Twistors are prepared putting a spiral wrapping of mo permalloy magnetic tape around copper carrier wire. This wrappi produces a spiral magnetic path arou the conductor when a current is pass along the tape and the carrier wi A number of these magnetic wires embedded in a strip of Mylar fil each with a plain copper wire alon side it for a return current carrier. T other coordinate of the grid is ma up of strips of copper foil 0.060 in wide, also embedded in a Mylar fil This conductor-bearing film is fold over the Twistor strip in such a w that one complete loop is formed; ea

loop of copper strip provides a single turn solenoid at right angles to the Twistors. For access to the memory, the open end of the solenoid (or "word coil") is connected to a biased ferrite core switch or transformer. Because of the square hysteresis loop characteristics of this core, it also provides a selection scheme for picking a particular "word coil" out of a matrix of such coils. Neither the ferrite core switch nor the Twistor-conductor grid stores information in itself; they are used only for access to the permanent magnet memory.

MEMORY OPERATION

The Twistor-conductor grid is used to sense the presence or absence of a field from a permanent magnet. The field inhibits the action of an electrical pulse through a "word coil" on the magnetic properties of the Twistor itself. If there is no magnet at a given intersection, a corresponding pulse is generated in the Twistor and read out. If a magnet is present, its field prevents the production of the Twistor pulse; and no signal is read out. The signal from the Twistor is about 6 millivolts at an impedance level of 10 ohms and is about 1 microsecond long. The computer interprets this signal or lack of signal to indicate a specific command and acts on it to do its computation.

By inserting a new card with a different arrangement of magnets, the memory can be easily and reliably changed to a new program when conditions require. Accuracy of registration in the program cards is assured by the use of guide pins, and the entire card is held in close proximity to the Twistor grid by springs. The separation of the magnets from the sensing wires is only a few thousandths of an inch. There are no wired connections between coordinate wires of the access grid or between the grid and the permanent magnet memory—their interaction results from proximity alone.

PRODUCTION DESIGN

The first step in the manufacture of the Twistor-conductor grid is the preparation of the magnetic tape used in wrapping the copper carrier wire to form the Twistor. Molypermalloy wire is first drawn to a diameter of approximately 0.001 inch then roll-flattened to a tape 0.0035 inch wide by 0.0003 inch thick. A specially designed test set continuously checks the magnetic quality of the wire, allowing identification of that part of the product which could cause faulty operation.

When the ultimate in quality and reliability is required . . . when there is no time for standby or interruptions . . . no room for component value variations . . . no tolerance of failure—then it's high time to specify MARKITE precision potentiometers. Here are only a few reasons why they provide performance beyond the expected:

• Linear stability for more than 50 million cycles • Substantially infinite resolution • Independent linearity to 0.05% in 1⅞" dia. units and 0.01% in 5" dia. units • Operation in ambient temperatures up to 200° C • Shock and acceleration resistance in excess of 100g • Rotational speeds up to 1,000 rpm • Meet Military Specifications

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CIRCLE NO. 23 ON INQUIRY CARD

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ONE OUNCE MAX.
SMALL SIZE
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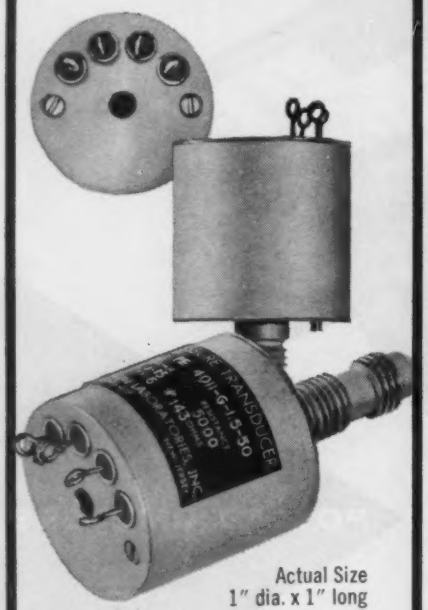
MINIATURE PRESSURE TRANSDUCER FROM COLVIN



Actual Size
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This new model of the Colvin Miniature Pressure Transducer Series 401 has all the outstanding features of the first model — plus a 50% reduction in weight.

High vibration performance ±35G to 5,000 cps
Pressure ranges Absolute, differential and gage pressures 0-3 to 0-400 psi
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Standard Nominal Potentiometer Resistances 400 to 10,000 ohms
Electrical Connection Pigmy receptacle or soldering terminals
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Write for complete information.

COLVIN
LABORATORIES, INC.
364 Glenwood Avenue, East Orange, N. J.

CIRCLE NO. 24 ON INQUIRY CARD

H. L. Stadler and D. G. Clemons, Bell Telephone Laboratories, discuss basic components of the Magnet-Twistor memory module, developed by Western Electric and Bell Laboratories. A partially assembled module is in the foreground, with a completed unit behind it.

The wrapping process required a development program of its own. A machine had to be designed which took into account the low strength of the materials involved, yet would wrap the tape about 3 mil (40 AWG) carrier wire quickly with a high degree of uniformity. High uniformity is necessary to minimize variation in the magnetic characteristics of the final assembly. An output of 300 feet of Twistor per hour is possible with the machines now in use. With a 45° helix, this requires 1,140 turns of tape per foot of carrier wire or a speed of 5,700 rpm for the wrapping head.

Drawing permalloy tape to these small dimensions and then applying it in helical form were significant "firsts" in this development.

Twenty-six pairs of Twistor-return wires are then laminated between sheets of Mylar tape. These wire pairs are positioned on 0.100 inch centers across the width of the tape; the separation between a Twistor and its associated return wire is 0.020 inch. A memory module is built by interweaving the Twistor tape, the copper "word coils" and the plastic magnet cards. An array of tiny transformers is made, one connected to each "word coil" of the module. A registration mechanism insures that the magnets on any program card are aligned over the proper bit position. The unit is assembled into a compact, mechanically rugged package.

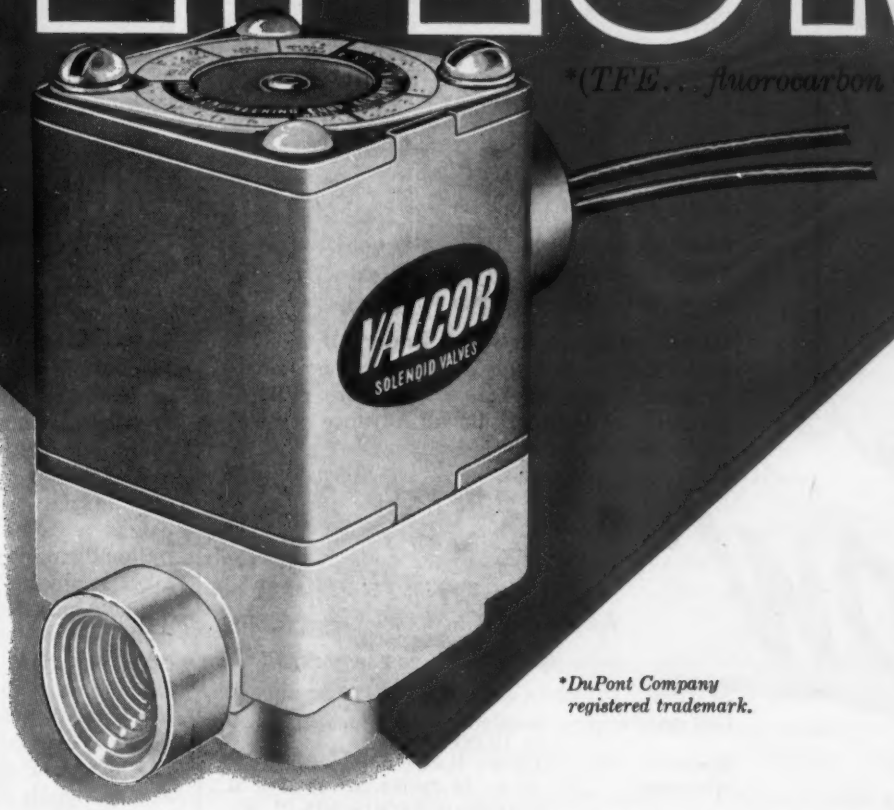
A special test set, which is essentially a computer in itself, was required because of the complexity of the module and the variety of conditions under which the memory module might be required to operate.

The Twistor got its name from early work by A. H. Bobeck of Bell Laboratories, who showed that a wire with a twisted magnetization could be switched by either current flowing down the wire or by current flowing down another wire perpendicular to it. If such wires were then woven into a grid with plain copper wires, the intersections could be used to store bits of information in a temporary computer memory.

Circle No. 115 on Inquiry Card

Only VALCOR makes solenoid valves of TEFLON*

*(TFE... fluorocarbon resin)



*DuPont Company registered trademark.

Now, from the company that pioneered the use of Nylon and PVC in solenoid valves for corrosive service, comes a solenoid valve with a **molded body and diaphragm of Teflon** that is **chemically inert and corrosion-resistant to virtually any corrosive medium you are now using.**

Valcor solenoid valves made of all Teflon are ideal for **critically** corrosive applications and where long life is essential. They will outlast and outperform steel. Available in a variety of sizes and pressure ratings. Stocked for immediate delivery. Write today for complete technical data.

VALCOR SOLENOID VALVES

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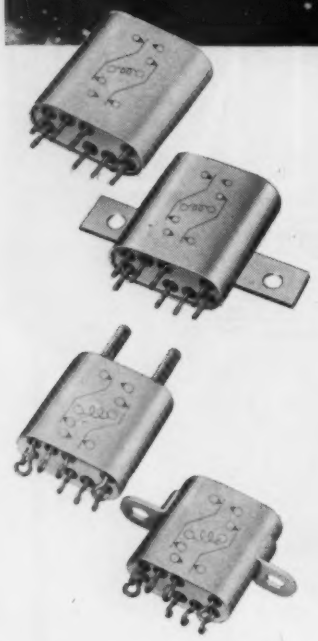
CIRCLE NO. 25 ON INQUIRY CARD

crystal can size relays by ADVANCE



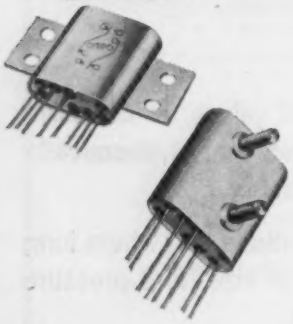
—these construction features assure exceptional reliability:

Positive sealing. Advance's use of induction heating cuts rejects from faulty soldering to a negligible figure. Soldering is accomplished at high speed, hence damage to the relay due to heat transfer is eliminated.

RADIFLO testing for leakage is used to detect leaks as small as 10^{-8} cc/sec. All relays that pass this test will function after long shelf life.

RIQAP program approval. Under RIQAP, the Signal Corps constantly checks Advance's quality control and inspection, to insure military standards of reliability for all Advance cust... ers, both military and ind...

NOW CRYSTAL CAN RELAY MV 7033 meets the requirements of MS24250-6 (USAF)



SPECIFICATIONS

Coil resistance:	Available in 7 values, from 30 to 10,000 ohms.
Shock:	50 G's for 11 milliseconds.
Vibration:	10 to 34 cycles per second at maximum excursions of .4". 34 to 2000 cps 20 G's acceleration.
Operating power:	Pull in power 250 milliwatts at 25°C.
Contact rating:	2 amps resistive at 32 VDC or 115 VAC.
Life:	100,000 operations minimum at rated current.
Weight:	0.45 ounce.
Size:	7/8" high x 51/64" wide x 23/64" deep.

ELGIN-ADVANCE RELAYS

A PRODUCT OF ELECTRONICS DIVISION
ELGIN NATIONAL WATCH COMPANY
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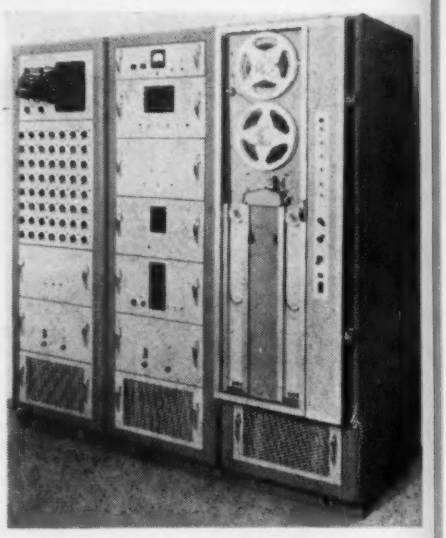
CIRCLE NO. 26 ON INQUIRY CARD



Analog Signals Compressed Into Digital Data

High-speed translator and editor system compresses an input of analog voltage data into a computer-compatible digital magnetic tape recording of only significant data. Input can be direct from any number of channels, or from analog magnetic tape recording. To save time and tape if a recording input is chosen, playback speed is a maximum of 100 times recording speed. Signal frequency is a maximum of 600 cycles per second.

The system recognizes and digitizes only during defined voltage peaks, bands, or zones which are established by mathematical criteria. The design takes a unique approach to analog-to-digital conversion by digitizing the data before the system performs its other functions. This eliminates inaccuracies or ambiguities typical of analog data. A maximum of 10,000 samples/sec. can be digitized.

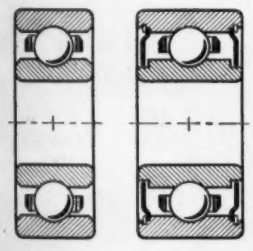
A magnetic core buffer storage holds analog signals to allow time necessary for digitizing and to make possible an uninterrupted synchronized flow of digital data, even though the input of analog signals may vary.

Time reference information and measurement identification codes added to the tape during the analog phase make it easy to reconstruct the signals in such a manner that the data can be treated mathematically as though all channels were instantaneously and simultaneously sampled at a defined time and interval.

Any existing library of analog data can be translated and edited by the system. Consolidated Electrodynamics, Pasadena, Cal.

Circle No. 100 on Inquiry Card

BARDEN "T" retainer combines aluminum and phenolic for greater strength, superior performance



"T" retainer bearings are available in chrome or stainless steel, open or shielded, from .5000" O.D. to 3.3465" O.D. in standard widths. Also available: extra-wide shielded sizes with increased lubricant space for still longer life. For complete technical information write for Engineering Data Sheet T-1.

Doubles bearing life in high speed applications

Power tools, gyro rotors, aircraft and missile accessories and other high speed applications require bearings that combine high load capacity and endurance at speed. To meet these exacting demands, Barden developed the "T" ball retainer which combines the advantages of phenolic with the strength of aluminum.

The two-piece "T" retainer has laminated phenolic center sections bonded to high-strength aluminum alloy side plates. It is securely joined by body-bound rivets tightly headed against metal at both ends. The retainer's thin cross section permits maximum exposure of balls and raceways to lubricant. Outer ring piloting provides optimum lubricant circulation.

These features, together with high load capacity, result in longer, trouble-free bearing life. For example, double shielded, grease lubricated "T" retainer bearings have operated continuously in textile spindles for more than 18,000 hours at 30,000 RPM.

Like other Barden advances in engineering and manufacturing, "T" retainer bearings solve a specific performance problem. Other Barden Precision ball bearings satisfy such extreme demands as:

- High temperatures (to above 400° F.)
- High speeds (to over 300,000 RPM)
- Low torque (to 10 dyne-cm. for 2 lb. load)
- Concentric rotation (to .00005" max. T.I.R.)

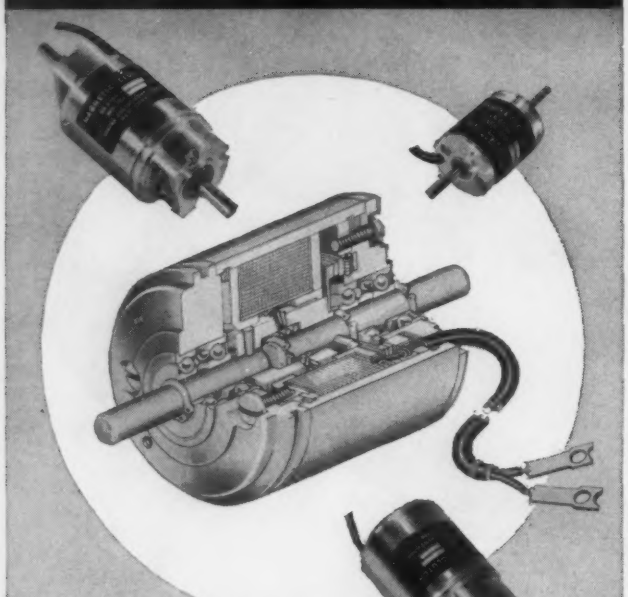
The complete Barden line includes sizes from .0469" bore to over 3" O.D., all manufactured to Barden Precision standards of dimensional accuracy, uniformity and reliability. Refer to Sweet's Product Design File (8h/Ba) for Barden catalog and bearing selection guide.

for reliability... specify **BARDEN PRECISION BALL BEARINGS**

THE BARDEN CORPORATION, 206 Park Avenue, Danbury, Connecticut
Western office: 3850 Wilshire Boulevard, Los Angeles 5, California

CIRCLE NO. 27 ON INQUIRY CARD

when you're engineering for
highest precision
and reliability
you'll be wise to specify:



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Roosevelt Field, Garden City, New York

1RV60

CIRCLE NO. 28 ON INQUIRY CARD

SYSTEMS DESIGN

DIGITAL READING OSCILLOSCOPE

Scope-Output Can Be Fed Directly To Digital Equipment For Recording Or Data Analysis

Incorporating a unique digital readout system, a new high-frequency oscilloscope is said to be the first to be classed as an analog to digital converter. As a result of direct reading, accuracy is increased because the possible errors in interpolating and converting mathematically have been greatly reduced. Repeatability of accurate readings provides a new dimension in scientific measurement techniques. According to the Allen B. DuMont Labs., the readout eliminates countless man-hours normally consumed in measuring, reading and interpolating the standard visual signals from the face of the scope. DuMont estimates that up to 40% of all engineering time, where the use of an oscilloscope was required, was devoted to either reading or interpolating of waveform patterns.

Two, 40-pin connector plugs coded in a ten-line arrangement for each digit provides for printing remotely on accessory equipment or relaying the information to a computer via punches cards or tape. An analog voltage proportional to the digital readings may be introduced directly into an analog computer or pen writing recorder.

Direct numerical readout also makes it possible for unskilled production workers to use oscilloscopes in production control processes. After an original set-up by an engineer, the operator can read the amplitude and time measurements as actual digits on the scope panel.

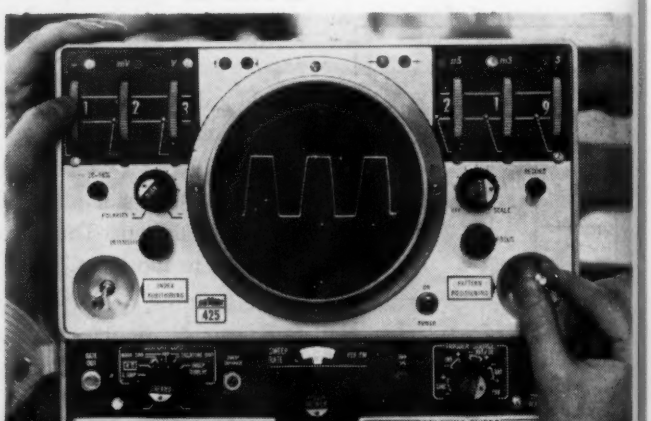

Fig. 1 Digital reading DuMont oscilloscope. Direct numerical portrayal of time and amplitude is accomplished through the manipulation of two measuring dots on the face of the scope which are moved by joy stick controls and thumb wheels so that they are aligned with the waveform presentation being studied. By standardizing dot position, repeatable measurements, within an accuracy of 2%, can be applied to peak-to-peak voltage investigations as well as studies of instantaneous voltages with respect to ground, rise and fall times, elapsed times, repetition times, or frequency, and phase angles between two identical waveforms.

Fig. 2 a protec where I manded contains the othe voltage ray tube X plug-I power s screws a signed w Whereas amplifie satility is design the seco instrume electroni

DIGITAL

On the stick po play do two dot position position thumb w to move the trac wheels, digital d amplitu millisec need fo adjustm any hur

Measu system t panel, w up 10% tude. O DuMont polation

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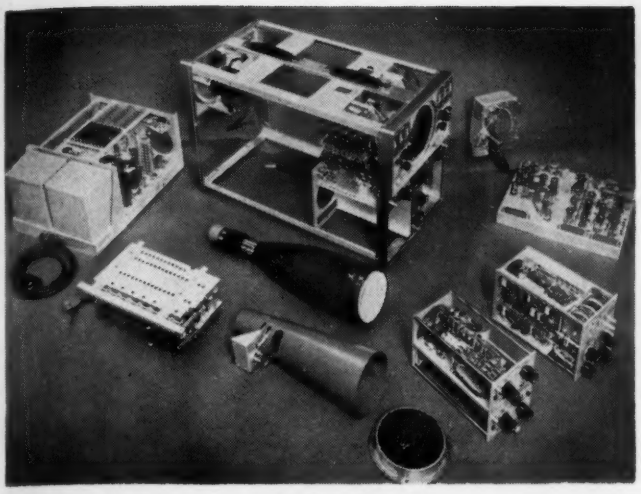

Fig. 2 Modular construction of the DuMont oscilloscope is a protection against prolonged down-time and obsolesence where higher performance, improved techniques are demanded. Shown are the main frame (top, center) which contains the digital readout front panel and circuits and the other modules including: (from left to right) the low voltage power supply, the distributed amplifier, the cathode-ray tube, the cathode-ray tube shield, the bezel, the Y and X plug-ins, the sweep chassis circuits and the high voltage power supply. All modules are detachable by means of screws and pin connectors. The distributed amplifier was designed with a canted tube alignment to minimize coupling. Whereas some oscilloscopes are engineered for one plug-in amplifier, the new unit automatically permits a higher versatility of operation with a second plug-in cavity. DuMont is designing additional plug-in units that can be employed in the second cavity that will actually make it possible for the instrument to be incorporated in almost any production, electronic, or automated system.

DIGITAL READOUT SYSTEM

On the face of the instrument, six thumb wheels and a joy stick positioner control are employed to traverse two display dots across the face of the cathode-ray screen. The two dots are moved in unison by the joy stick or index positioning control. When one dot—the indexing dot—is positioned on a reference part of the waveform, the two thumb wheels sets (horizontal and vertical) are then used to move the second (scaling) dot to the other position on the trace where the measurement is to be taken. The thumb wheels, while moving the scaling dot, also control the digital display, and when the two dots are positioned, exact amplitude and time are read directly in volts, seconds, milliseconds or microseconds. The reading eliminates the need for any dial multiplication, interpolation and parallax adjustment, and is reputed to be far more accurate than any human measurement.

Measurement of rise time is modernized by the digital system through the use of a pushbutton on the face of the panel, which, when activated, will move the indexing dot up 10% and the scaling dot down 10% of the total amplitude. Original settings are not affected, and according to DuMont, rise time readings may be achieved without interpolation and with a highly accurate degree of repeatability.

Basic unit consists of five modules which may be interchanged: low voltage power supply; distributed amplifier; X chassis circuit; main frame; and high voltage power supply. Cathode-ray tube has 12,000 volts for overall acceleration and the scope operates from d-c to over 60 megacycles (down 3db at 35mc). Two plug-ins permit versatile operation in the Y and X amplifiers and in the delaying sweep field.

Circle No. 108 on Inquiry Card

Aren't You Entitled to the Best?

If you were a doctor, you wouldn't use a cheap stethoscope. If you were a violinist, you wouldn't think of playing a concert on a scratchy fiddle.

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If it ever happens, that any part of a LOCKTITE Holder breaks in normal usage, the entire holder will be replaced free of charge.

#9030 Imported CASTELL Black Gold Refill Leads fit any standard holder. Perfectly mated with LOCKTITE. Sold by all good Dealers.

A.W.Faber-Castell Pencil Co., Inc., Newark 3, N. J.

CIRCLE NO. 29 ON INQUIRY CARD

Advanced Techniques in Printed Circuitry

PRINTED CIRCUIT LAYOUT

New Method Cuts Cost And Time

In preparing printed circuit layouts, General Electric's Heavy Military Electronics Dept., Syracuse, New York, has been using the usual inking and taping methods. Although results were satisfactory for early printed circuit work, taping could not be relied upon to meet standards required for new, highly specialized circuits.

A new system, developed in cooperation with the Keuffel and Esser Co., Hoboken, N. J., incorporates three new techniques: specially designed scribing instruments; a scribe coat, Mylar polyester-base film called Stabilene; and a photographic, peel-coat variety of the same film.

Briefly, this is how the system works:

- Standard circuitry is scribed on scribe-coat Mylar polyester base Stabilene film. This is called the scribe master.
- The photographic peel-coat Stabilene film is exposed to the scribe master. This produces a line image on the photo emulsion layer of the sheet. The area between each translucent line, not the line itself, is actually the circuit path desired.
- While in the developer, these image lines are eaten away down to the peel-coat layer.
- The sheet is then wiped with an alcohol dampened cloth, further dissolving the image lines through the peel-coat layer and down to the Mylar base. Valleys two layers deep result.
- The photo emulsion layer of the sheet is then washed away in a Clorox bath leaving valleys now only in the peel-coat.
- Finally, the coating between each translucent line is peeled away leaving finished circuit paths. This final master and file copy can be further reprinted.

The steel alloy points of the new scribe tools are made in graduated widths and cut extremely sharp, precise lines. The use of constant-width scribe points in turn eliminates minute variations in circuit line widths that were often encountered in pen and ink work, where the amount of ink in a pen can alter the line thickness and clarity. The Stabilene film on which the scribing is done contains grid lines for accurate positioning of the board element. The film permits precise reproduction and maintains constant line character under extreme temperature and atmospheric conditions.

The new system eliminates opaquing and makes the usual inking and taping methods virtually obsolete for preparing large numbers of complex printed circuit layouts. The scribing method is especially suited to jobs requiring irregular shapes, long runs, and complex grounding and shielding to separate high frequency leads from one another.

In addition to its high degree of accuracy and flexibility, this new scribing method can cut cost and time. Optimum use can be made of the board area since the width and length of runs, as well as pad, (connection) sizes are not limited by standard tape sizes. Using specially formulated fluids, drawing changes can be made easily during any one of the three steps: the original scribed layout, peel-coat negative (intermediate step), or the final layout. An additional advantage of this new method is that the printed circuit masters can be made in either position or negative form, depending on which surface is to be stripped off.

Circle No. 106 on Inquiry Card

AUTOMATED SOLDERING PROCESS

Process Geared To Volume Production Also Useful For Short Batch Runs

Systems designed for fast, low cost volume production sometimes provide improved product reliability sufficient to warrant their use for short batch operation.

Such is the case with an integrated soldering system, designed by Electrovert, Inc., New York, to provide fast, higher quality soldering of printed circuit boards or other electronic and machine component assemblies. Product conveying flux application, solvent removal, flux and board preheating and soldering are completely integrated into one automated system, called Flowsolder. Kearfott Co., Inc., New Jersey, installed this system for short batch operation because it offered greater joint uniformity and positive soldering. The system practically eliminated cold joints, unsoldered joints, etc. and has brought about a reduction of rejects. Mr. Kaplan, Senior Project Engineer, of Kearfott stated that "One of the main advantages of the Flowsolder unit for our operation is its excellent heat control. It allows positive control of soldering temperatures without damage to the heat sensitive components we attach to the printed circuit boards. Using properly prepared boards with this unit, all connections are soldered because they must all pass through a solder wave."

Operational speed was not a major factor in Kearfott's selection of the Flowsolder unit. The main concern was joint reliability and reduced rejects. However, they are benefiting from the faster automated processing. They estimate that a good hand-soldered board would require about 20 to 30 seconds of an operator's time per joint to produce joints acceptable under military specs. For example, a board with 50 joints, would require about 1000 seconds (17 minutes) to be hand-soldered. The automated process would allow soldering each such board in 2 to 3 seconds. To this time a 50-second "set-up" time should be added, during which the operator applies flux to the board, sets the board into its holder and starts the conveyor. The total time per board, by the Flowsolder method, is about one minute.

Circle No. 107 on Inquiry Card

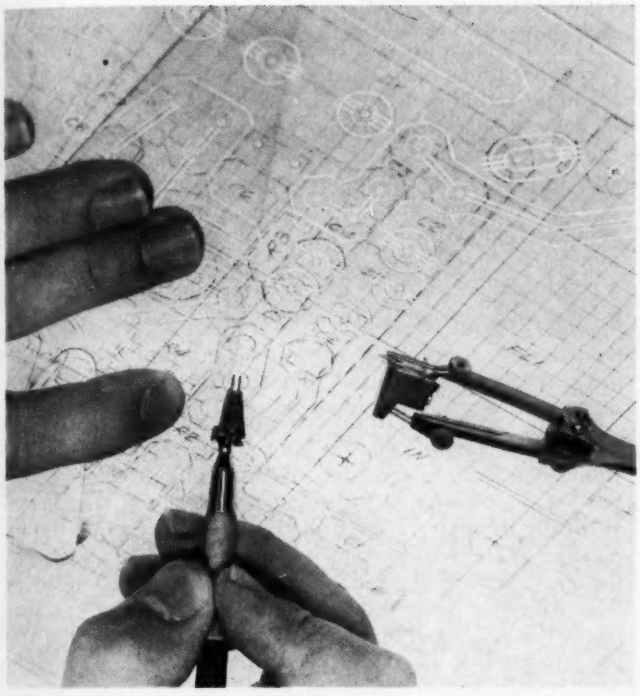

Fig. 1 Specially designed scribing instruments equipped with unique spring-type shock absorbers are used to "outline" circuit paths and connection pads. These devices maintain precise accuracy on curved as well as straight lines.

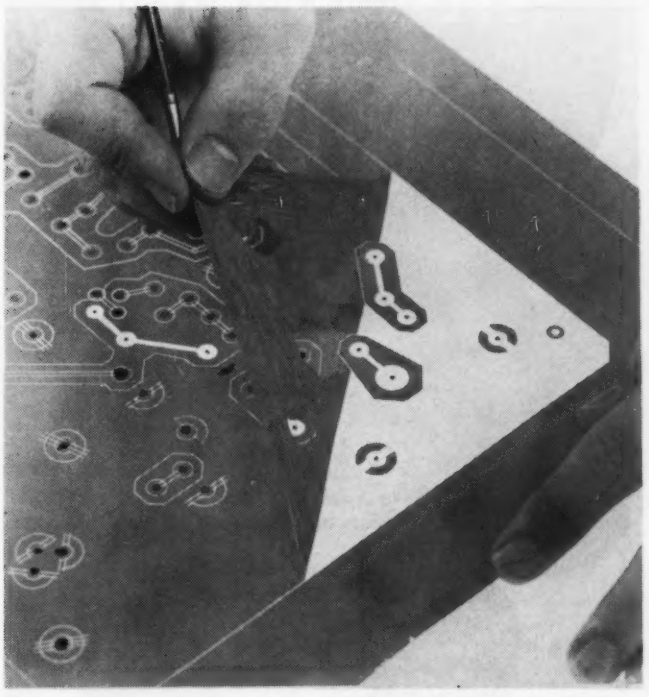

Fig. 2—After the scribe master has been processed photographically, the film coating between each translucent line is peeled away, leaving the finished circuit paths and connection pads.

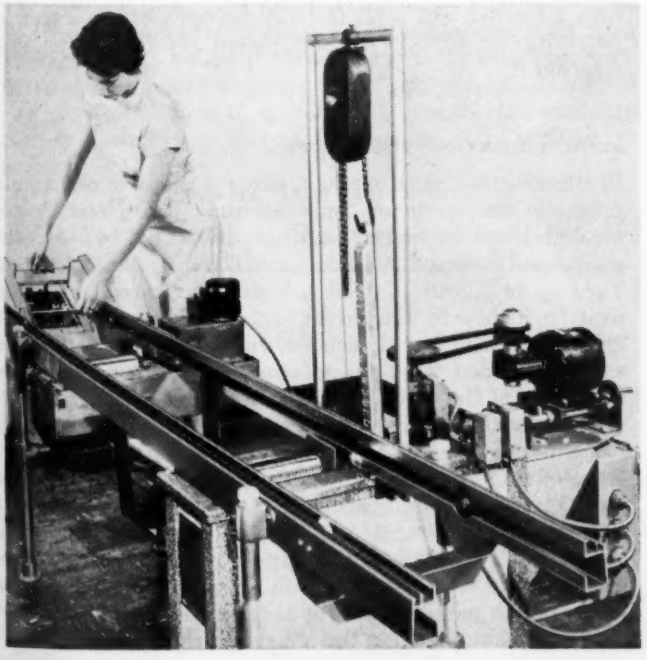

Fig. 1 The Flowsolder system. The operator places carrier and board on the Flowsolder Production Line conveyor track. From here, the board passes along the transfer mechanism at controlled speeds ranging from 1 to 15 feet per minute. A single pass of the board through the flux wave applicator will be sufficient to deposit a uniform film of liquid flux on the bottom surface of the board. The washing movement of the flux wave promotes capillary action, allowing improved fluxing of all types of boards, including those with plated-through holes, eyelets and tubular rivets. After fluxing, the board travels over the infra-red heating unit where the flux solvent is driven off and the flux action initiated. Preheating prior to the soldering operation reduces thermal shock and resultant warpage of boards. In addition, pre-heating of the boards reduces rate of cooling after soldering, eliminating "icicling" which results when excess solder coo's before it can drain from the boards. When the board contacts the smooth, constantly moving solder wave it meets ideal soldering conditions. The surfaces to be joined are actually "wetted better" as a result of the improved fluxing action. More uniform soldering temperatures are possible because of the constant renewal of properly heated molten metal at the wave crest and smaller board areas in contact with the wave at any one time (two inches maximum length). There are no dross or oxide problems to cause faulty connections because the constantly moving wave is drawing fresh, oxide-free metal from deep within the solder pot.

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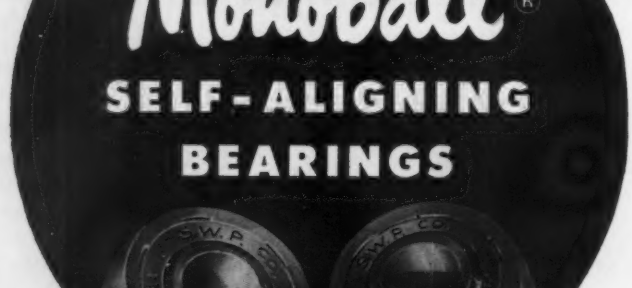

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CIRCLE NO. 30 ON INQUIRY CARD

NEW TECHNIQUES

DETERMINING THE THERMOELASTIC PROPERTIES OF METALS

Two Simple Dynamic Tests

Elevated temperatures attained in modern aircraft and missile applications have created a need for metal springs that maintain stable deflection characteristics over a wide range of environmental conditions. However, to design alloys for these springs, basic data are necessary on the elastic constants of materials suitable for spring fabrication.

The National Bureau of Standards has adapted two simple dynamic techniques to the determination of the thermoelastic properties of metals and alloys. One method uses a pendulum assembly to test wire specimens, and the other, a sonic vibration apparatus for rods and prisms.

PENDULUM ASSEMBLY

The equipment used in the pendulum method consists of an oven, photoelectric cell and lamp, timer, counter, and electronic temperature recorder. A frame about the oven supports a 3-foot long, 0.5-in. diameter steel rod that extends vertically through a hole in the top of the oven into the heat chamber. The wire specimen is suspended from a chuck on the lower end of the rod. Another chuck, firmly fixed to a 6-in. diameter brass disk, grips the lower end of the specimen. When a small amount of twist is applied with a starting arm fitted to the upper portion of the rod, the pendulum oscillates about the axis of the specimen.

The photoelectric cell and lamp, mounted just outside the rear of the oven, are aligned with two holes in the oven wall. Once in each half cycle of oscillation, light from the lamp strikes a small mirror attached to the pendulum assembly, and is reflected back to the cell. The cell, thus energized, operates the counter and timer until a predetermined number of oscillations is registered. The shear modulus of the wire is then computed from the resonant frequency derived for the specimen and the dimensions and masses of the pendulum assembly. Frequency range of this test is from a fraction of a cycle to 10 cycles per second. Test temperatures up to 525° F are shown on the temperature recorder.

SONIC VIBRATION TECHNIQUE

In the sonic vibration method, either a rod or a rectangular prismatic bar specimen, approximately 6 in. long, is suspended from an electromagnetic driver by two asbestos strings and enclosed in a furnace which operates at temperatures up to 1,000° F. The specimen is excited to its resonant frequency by the driver and a variable audio oscillator. A crystal pickup detects the vibrations which are shown as an expanded wave on a cathode ray oscilloscope. The frequency of the oscillator is then adjusted to the frequency of the specimen, indicated by the amplitude of the oscilloscope trace, and this adjusted frequency is measured with an electronic events-per-unit-time counter.

From the measurements thus obtained, Young's modulus can be computed for rod specimens. In using the apparatus for tests on rectangular prismatic bar specimens, the prisms can be made to vibrate either in tension or torsion, so that both Young's modulus and the shear modulus may be determined without changing the mode of suspension.

Electrically Exploded Wires

Based on a year-long study, Electro-Optical Systems, Inc., of Pasadena, Cal., proposes a variety of new applications for electrically exploded wires. Key to these applications lies in the technique of switching tremendous amounts of current into thin wires in millimicrosecond time. This fast switching capability evolved from work done at Electro-Optical Systems in the development of its 5 millimicrosecond Kerr Cell camera. The method allows many times the material's vaporization energy to be dumped into the wire, creating temperatures above 100,000° C and pressures in the megabar range. Specific impulses of 1000 seconds have been achieved in an exploding aluminum wire, and a 1000 to 5000 second range appears possible. Other types of wire used in the experiments have included iron, copper, gold, silver, nickel, tungsten, molybdenum, tin, titanium, zinc and cadmium.

Wire dimensions are 1 mil in diameter and about 1/4 of an inch in length. A capacitor of .002 and .02 microfarads charged to 10 to 20 kilovolts is suddenly discharged into the wire where the entire circuit inductance varies from 0.1 to 0.03 microhenrys. Voltage is switched across the wire in about 7 millimicroseconds and currents of several thousand amperes flow into the wire before it explodes. Vaporization processes typically take place in 50 to 100 millimicroseconds. Actual switching of these tremendous currents is triggered first by a hydrogen thyraton, a fast switch which activates a trigatron (triggered air spark gap) that dumps the current into the wire.

Impulses obtained by explosion of a wire or film could provide a space vehicle with 2 to 10 times the specific impulse presently obtained by chemical means. This method would provide a better thrust-power consumption ratio than many currently proposed electrical propulsion systems.

Exploding wire phenomena may also provide an answer to the problem of obtaining hypervelocities on a laboratory scale for high speed impact studies. Dense vapor or plasma produced by exploded wire possesses impact characteristics similar to solid materials and could be accelerated to 20 to 30 kilometers per second.

Explosion of tungsten wire has provided interesting possibilities for use in space communications, as well as terrestrial searchlight operations. Surface temperatures of 5,000 degrees centigrade, coupled with superheated interior, would give such a light source excellent visibility and large light output.

Electro-Optical Systems has placed great emphasis upon advanced instrumentation techniques in the exploding wire program and is believed to be the first to simultaneously record measurement of both voltage and current across the wire with resolution to a billionth of a second, enabling them to determine power and energy input, as well as resistance.

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WORTH FILING

Precious Metal Electroplating

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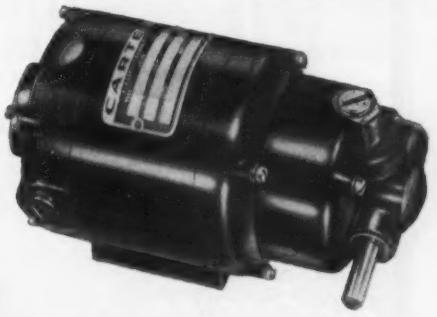

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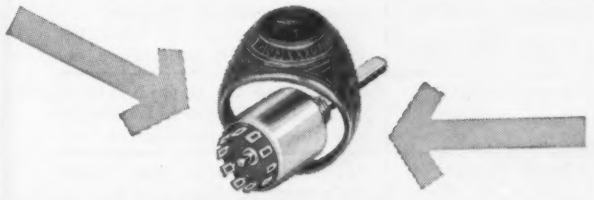

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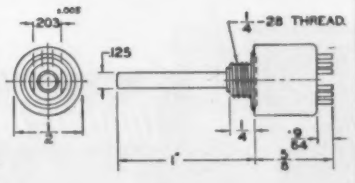

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CIRCLE NO. 33 ON INQUIRY CARD

NEW TECHNIQUES

ELECTRON BEAM WELDING AND MACHINING

Precision Process Packs Energy Density of 600 Millions Watts Per Sq. Inch

An instrument known as the Hamilton-Zeiss electron beam machine can cut holes finer than a human hair through, or surface-treat, melt or weld virtually every material known today including tungsten and the exotic new metals.

A typical installation comprises six basic elements:

- An electron gun which develops a precisely-controlled beam of electrons of high-energy density.
- A vacuum chamber and work table within the chamber on which the target is mounted. This includes vital equipment for extremely accurate positioning of the target.
- A high-vacuum pumping system capable of creating a near-perfect vacuum (about four-millionths of an inch of mercury).
- An electronic control system for manipulating the electronic deflectors and lenses that control the size and programming of the electron beam.
- A precisely-regulated high-voltage power supply.
- Miscellaneous monitoring instrumentation.

Used as a welding machine, it handles, comfortably, stainless steel producing T sections 60/1000s of an inch thick from sheet stock at a rate of two feet per minute. It will butt-weld 3/8" stainless steel at 1/3" per second, and has, in the laboratory, welded through one inch of stainless steel. It does this without distortion of the piece and with minimum grain growth in the weld area, the first because of the narrowness of the heat affected area (depth-width ratios as high as 20 to 1), the second because of extremely rapid heating and cooling (low total energy input to work piece).

The flexibility of design and the precise focusing of the electron beam permit welding of complex shapes in hard-to-weld metals. A major improvement in the welding of reactor cores has been one of its major benefits.

MACHINING

Electronics manufacturing appears to be a particularly promising area for the process because of the accelerated development of super-miniaturization of electronic components. Some of these components require working with tool diameters so small as to be unfeasible for mechanical processing. When used for machining, the process permits creation of accurate holes and slots in the hardest materials as small as about 0.008 of an inch.

Energy density during drilling runs as high as the equivalent of 600 million watts per square inch. Even higher energy and density and much smaller holes and slots are contemplated in the near future. Most of the energy used in machining is dissipated as vaporization of the material rather than into thermal heat, resulting in extremely low relative temperatures in the region adjacent to the machined area. For example, with a 11,000° F temperature at the target point, a temperature of only 550° F is registered one micron away from the edge of the cut.

The process may be controlled by electrical relays, or by complete electrical and mechanical automation. In the laboratory, paper tape, magnetic tape and television controls have been used successfully. The machine is capable of handling up to 10,000 jewel watch bearings in a load, drilling each one in about six seconds and showing remarkably high beam efficiency of about 90 per cent. Hamilton-Standards, Windsor Locks, Conn.

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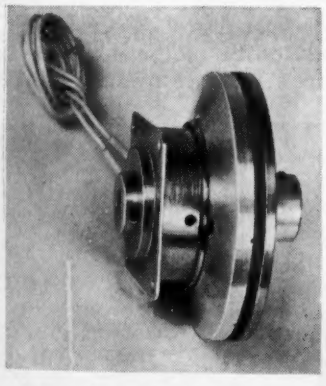

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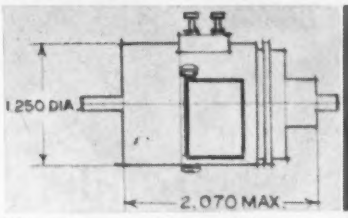

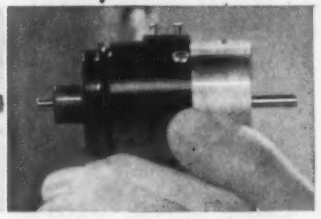

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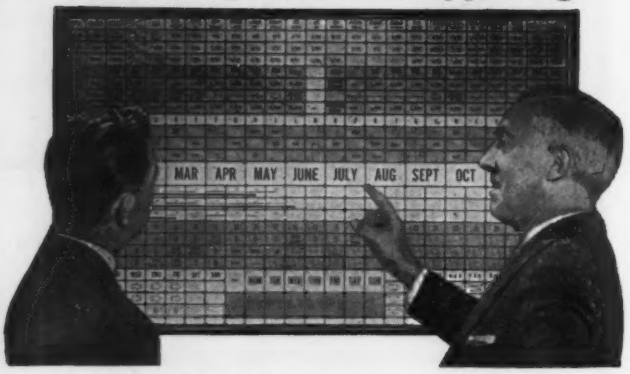

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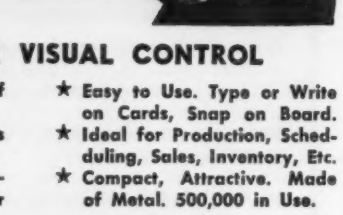

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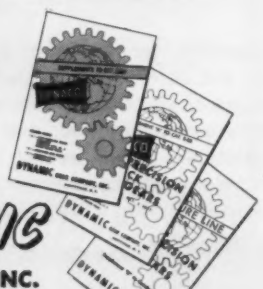

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NEW EPOXY RESINS

Superior Strength And Stability At High Temperatures

Differing from conventional epoxies in structure, reactivity and end-properties, Food Machinery and Chemical Corp.'s newly developed epoxies, called Oxiron, are polyfunctional, showing unusual versatility for curing through multiple epoxy and hydroxy groups and, uniquely, through double bonds. Oxiron resins appear to be well suited for a wide range of applications and are expected to find use in such fields as insulation, lamination, molding, adhesives, and coatings. They offer potential economies which should make them practical in many cases where, until now, epoxies have been excluded due to high costs. Cost advantages result from the use of higher proportions of relatively low-priced reactants and their lighter weight gives greater volume per pound than conventional epoxy resins. In addition, they differ greatly from conventional epoxies in the way they cure, offering advantages in handling.

Preferred curing agents for epoxies in insulating and encapsulating applications are anhydrides. The new epoxies react readily with anhydrides and combine excellent electrical properties with stability at high temperatures. Further, they can be cured at relatively low temperatures, thereby providing processing advantages and reducing the chance of thermal damage to electronic components. Oxiron exhibits low shrinkage and low exotherm on cure. The latter is of major importance in large castings and laminates. The new resins will wet glass fibers readily and show good adhesion on cure. Laminates with excellent strength to weight ratio can be prepared under low pressure in relatively short cure cycles. Oxiron polyamine cure systems show long pot life, suggesting wet lay-up and prepreg use with built-in storage ability. Combination peroxide-anhydride-glycol cures give high heat-distortion-point resins. Flatness of the heat distortion curves of the Oxiron resins means they're practical for use at temperatures ranging far above the heat distortion point itself.

Another significant characteristic of the new epoxies is excellent adhesion to surfaces. Presence of multi-functional

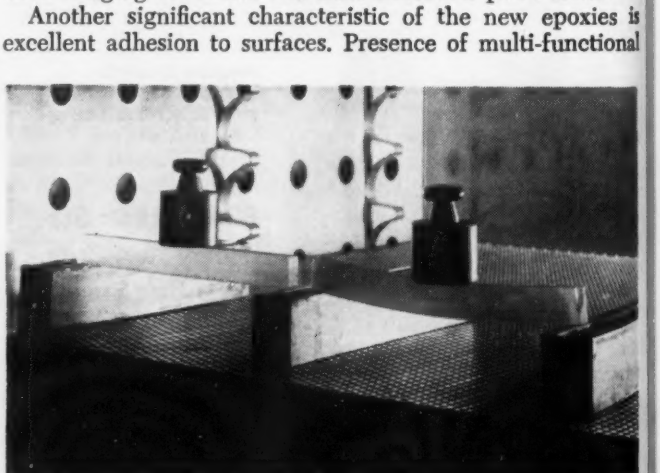

Fig. 1 Test of high temperature performance of the new resins. Heating in an oven at 210°C produces sag in a test bar of conventional epoxy resins (right). Oxiron 2000, is unchanged. This ability to withstand loads in high ambient temperatures is expected to be particularly valuable in the electronic aircraft and missile applications. The weights are 100mg.

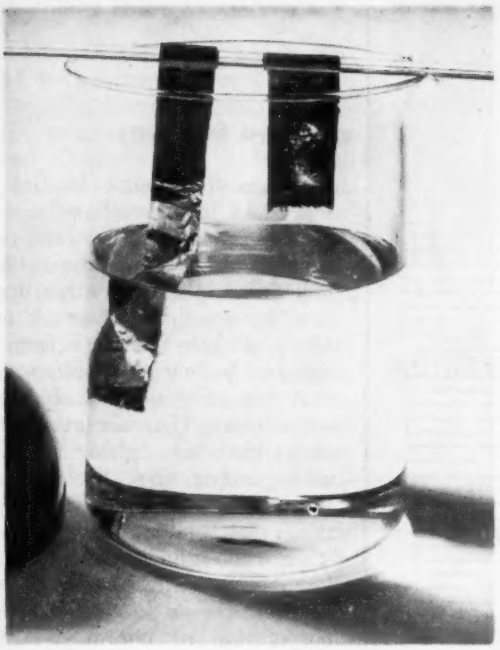

Fig. 2 New epoxies show excellent chemical resistance. One of the aluminum strips (left) has a thin flexible coating of cured Oxiron epoxy resin, the other is uncoated. Reagent is 25% hydrochloric acid. A transparent coating of Oxiron will protect metal from the ravages of acid, caustics, and moisture for long periods. In this test the rough edges, which are difficult to coat, were the first to show signs of attack.

groups within the structure provide versatility of cure, thus opening avenues to improved adhesive formulations. Resins are reactive to phenol formaldehyde resins as well as polyhydric phenols and provide opportunities of upgrading adhesives of this type.

Oxiron resins are also of interest for protective coating applications. They may be used alone or in conjunction with phenol formaldehyde or nitrogen resins, or through conversion of resin esters.

Circle No. 105 on Inquiry Card

Phenolic Molding Compound

Featuring a heat distortion point of over 500°F., a new asbestos-reinforced phenolic molding compound has been developed primarily for gears, electrical switchgear and control parts. New compound combines an impact strength of 2.5 average (ft. lbs./in. of notch) with a compressive strength of 12,000 psi, a tensile strength of 6,000 psi and a compressive strength of 22,000 psi (all average values). The reinforced phenolic molds to a high luster finish with a mold shrink of only .001"/inch. Rogers Corp., Rogers, Conn.

Circle No. 242 on Inquiry Card.

Class F Insulating Varnish

A new grade of clear insulating varnish that meets all requirements for Class F applications is a modified polyester resin-base material that withstands temperatures up to 155°C and can be used with any Class F magnet wire. Cost of the new varnish is about that for varnishes for Class A applications. As the varnish cures it becomes a tough, flexible coating that provides high dielectric strength and good adhesion and is highly resistant to moisture, oil and acids. Westinghouse Electric Corp., Pittsburgh, Pa.

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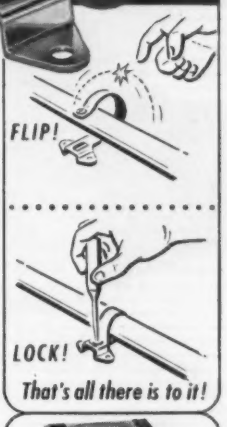

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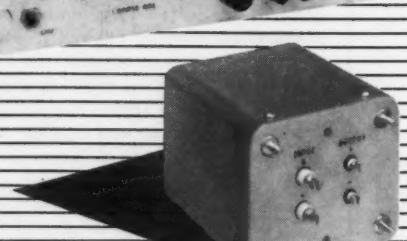

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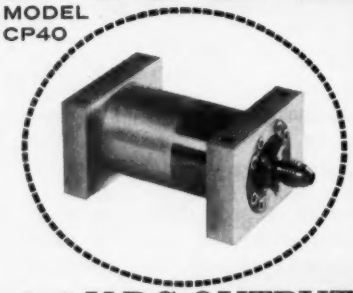

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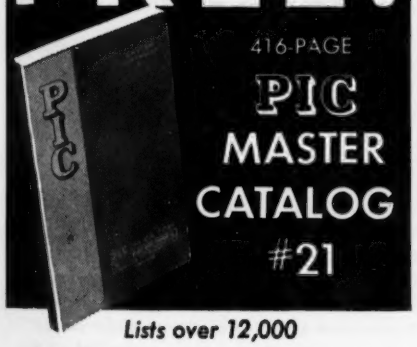

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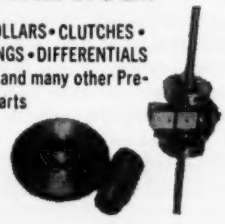

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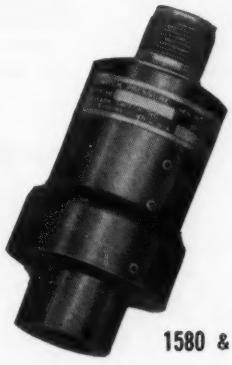

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WORTH FILING

Waveguide Data Chart

A new "Standard Waveguide Data Chart," is said to be one of the most complete listings of waveguide information available. Featuring military as well as EIA designation numbers, the chart shows virtually all required electrical as well as mechanical parameters for all waveguides in use today. Up to now, engineers have frequently had to devote considerable amounts of time to calculating certain characteristics, attenuation factors, power ratings, etc. The new chart provides the most commonly-used data, eliminating the necessity for calculations. Some of the parameters covered are: cut-off frequency, theoretical attenuation for both brass and aluminum waveguides, theoretical C. W. power rating, and the waveguide wavelength from the lowest to the highest frequency in any given band. Mechanical dimensions are also given for all waveguides, along with their tolerances.

Source: Narda Microwave Corporation
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Lock Nuts

A new 20-page catalog covers a complete line of spring tempered steel lock nuts, including regular hex, integral washer, acorn, wing and adjusting nut types. Details of design and locking principle, advantages, typical applications, dimensions, load ratings, materials and finishes are given.

Source: Palnut Company
Mountainside, New Jersey
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Precise Power Systems

"Precise-Power Systems for the Electronics Industry," contains applications, engineering data, subsystems and system-component operating characteristics, and recommended standard system combinations. The Electric Specialty Company defines its precise power set as a rotary electromechanical system, usually regulated and/or controlled by static circuitry, which performs one or more of the following functions: isolates the power system from power-line voltage transients; isolates the power system from static (slow) changes in power-line voltage; raises the power-line frequency, reducing the cost, size, and complexity of the dc power supplies in the system; performs the conversion to dc (regulated or unregulated) directly in a more economical manner.

Source: Electric Specialty Company.
Stamford, Conn.
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Surface Measurement

A pocket-size, 12-page, surface measurement reference manual containing important excerpts from the American Standard ASA B46.1-1955 for Surface Roughness, Waviness and Lay, covers classification of surface characteristics, stylus-type measuring instruments, precision reference specimens, roughness width cutoff, and notes on control of surface roughness. A conversion chart is provided for converting arithmetical average to root mean square averages in microinches. The Surfindicator, a production gage for finish control is also described.

Source: Brush Instruments
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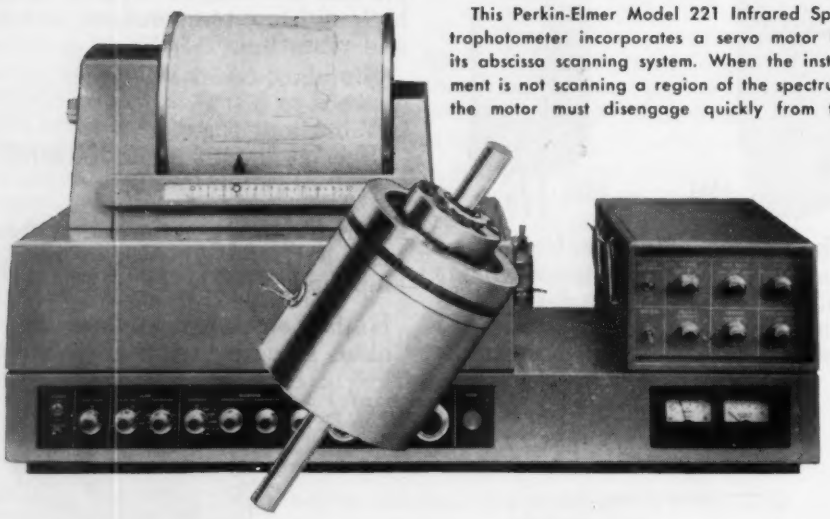

This Perkin-Elmer Model 221 Infrared Spectrophotometer incorporates a servo motor for its abscissa scanning system. When the instrument is not scanning a region of the spectrum, the motor must disengage quickly from the Littrow mirror drive and recorder system in order to allow the fastest possible abscissa run-back.

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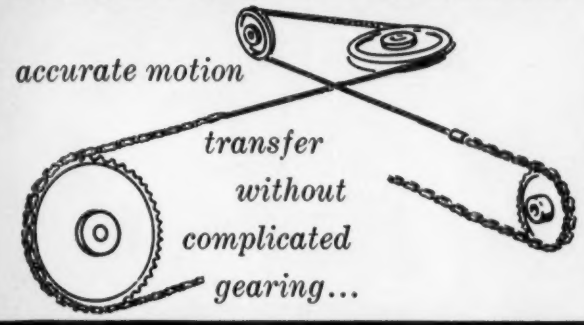

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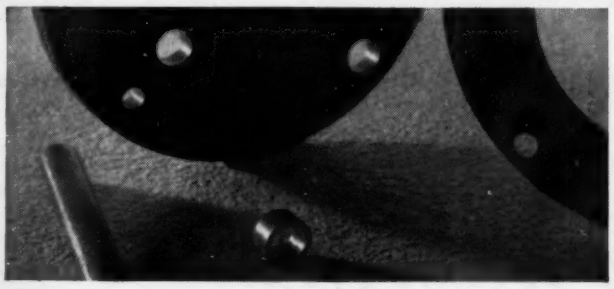

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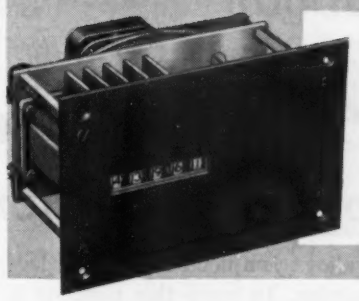

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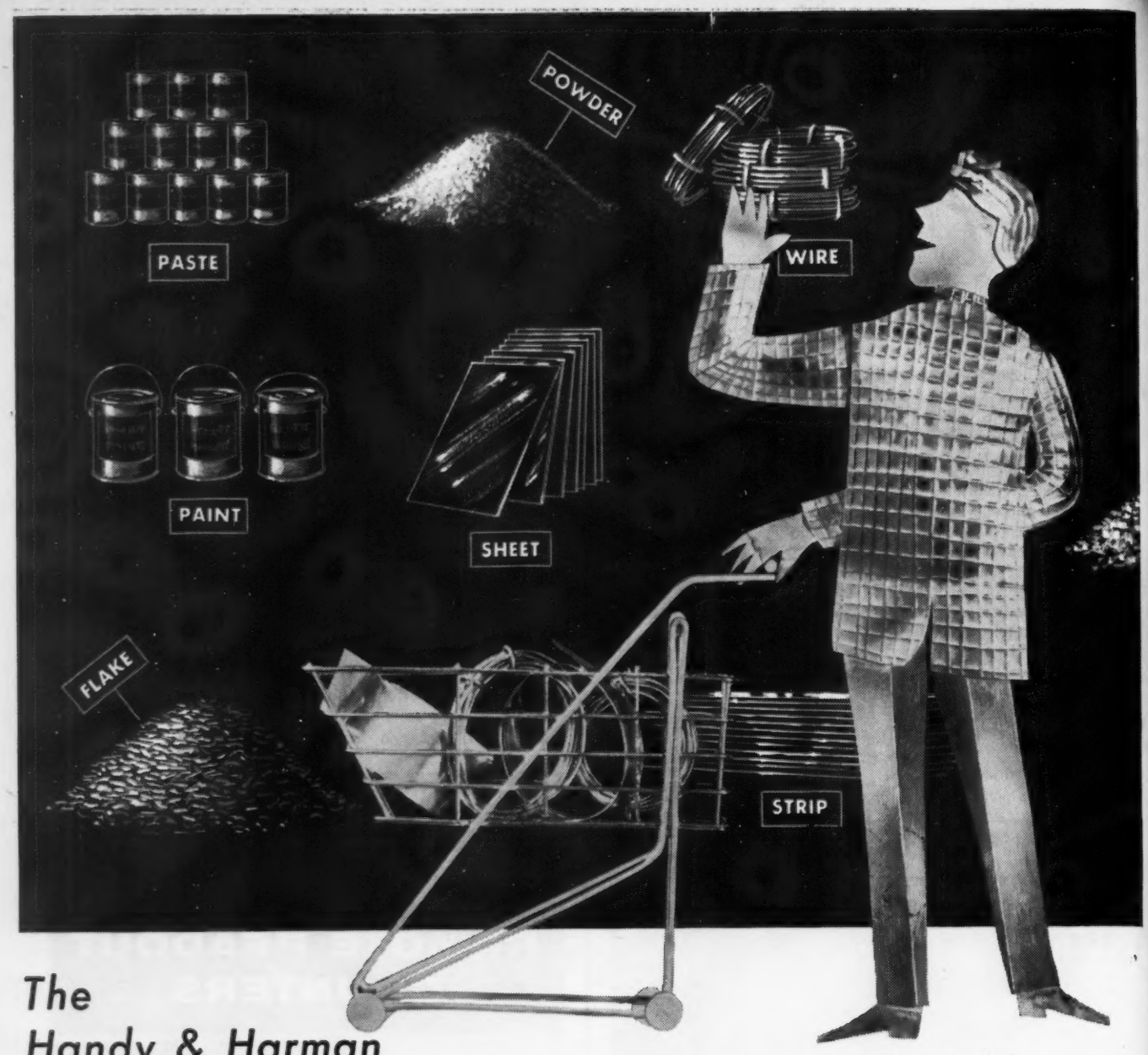

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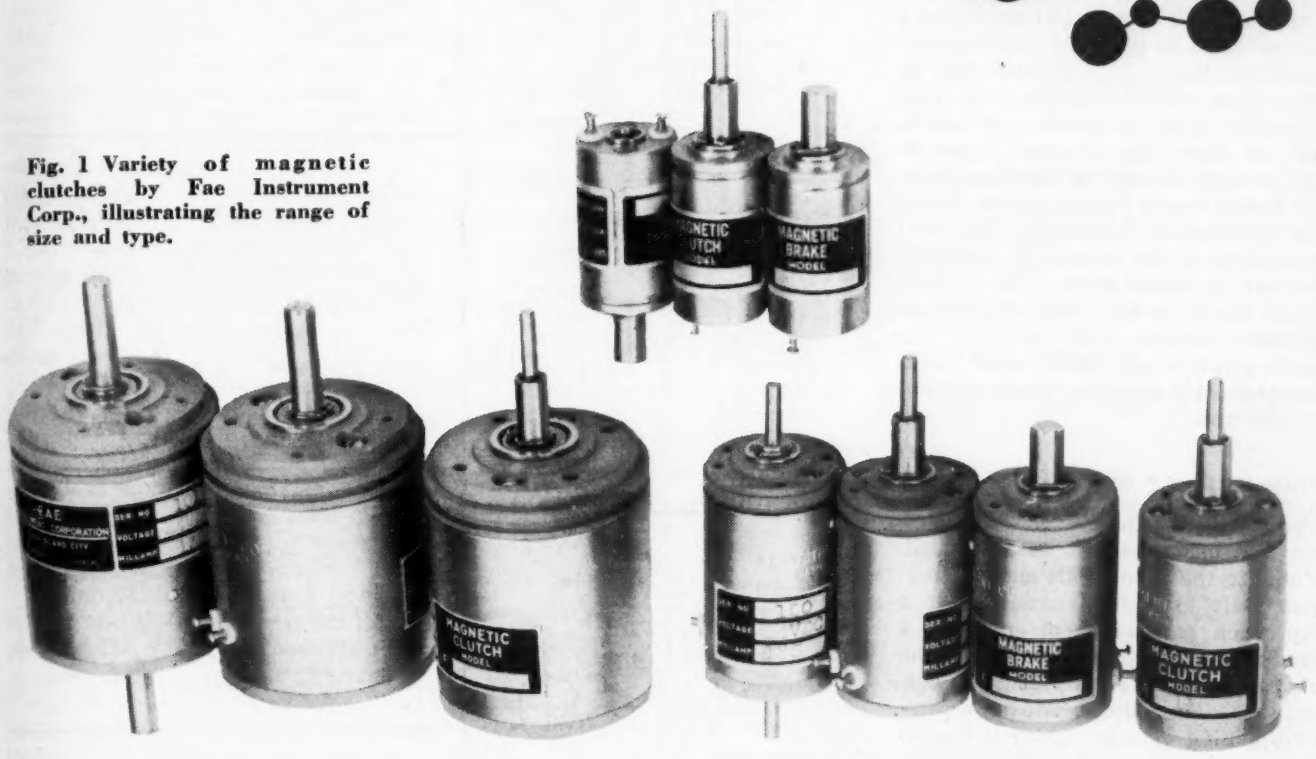


Fig. 1 Variety of magnetic clutches by Fae Instrument Corp., illustrating the range of size and type.

MINIATURE MAGNETIC CLUTCHES & BRAKES

Clutches and brakes are used to vary the coupling between shafts by means of relatively low power control signals. This coupling can either vary linearly with the magnitude of the control signal, or it can be of the on-off variety where the coupling is either zero or maximum.

The principal types of clutches of interest to electromechanical designers are magnetically actuated friction disc, hysteresis, eddy current, magnetic fluid, magnetic powder, crystal and "loudspeaker" clutches. For low power servo systems, the friction disc clutch is of maximum importance and this Components Digest will be confined to a consideration of that type. However, many of the application principles are basic to all types.

To permit a complete coverage, we are further restricting treatment to miniature varieties of the type commonly used in military applications and precision servomechanisms. Fig. 1 illustrates the range of these varieties and sizes.

CLUTCH APPLICATIONS

Friction disc clutches are of the on-off variety and do not function well where a substantial amount of slipping occurs during their useful life. When properly applied, they provide a firm coupling action between shaft or between shaft and ground. For this reason, they may be considered as analo-

TYPICAL CURVE	SCHEMATIC	MODEL
		C
		CF
		MC
		MCC
		SCB

TYPICAL CURVE	SCHEMATIC	MODEL
		B
		BF
		MB
		MBB
		MBC

Fig. 2 Specific types of clutching devices, and their coupling characteristics. The notations are Autotronics designations, for reference on Fig. 3.

COMPONENTS DIGEST

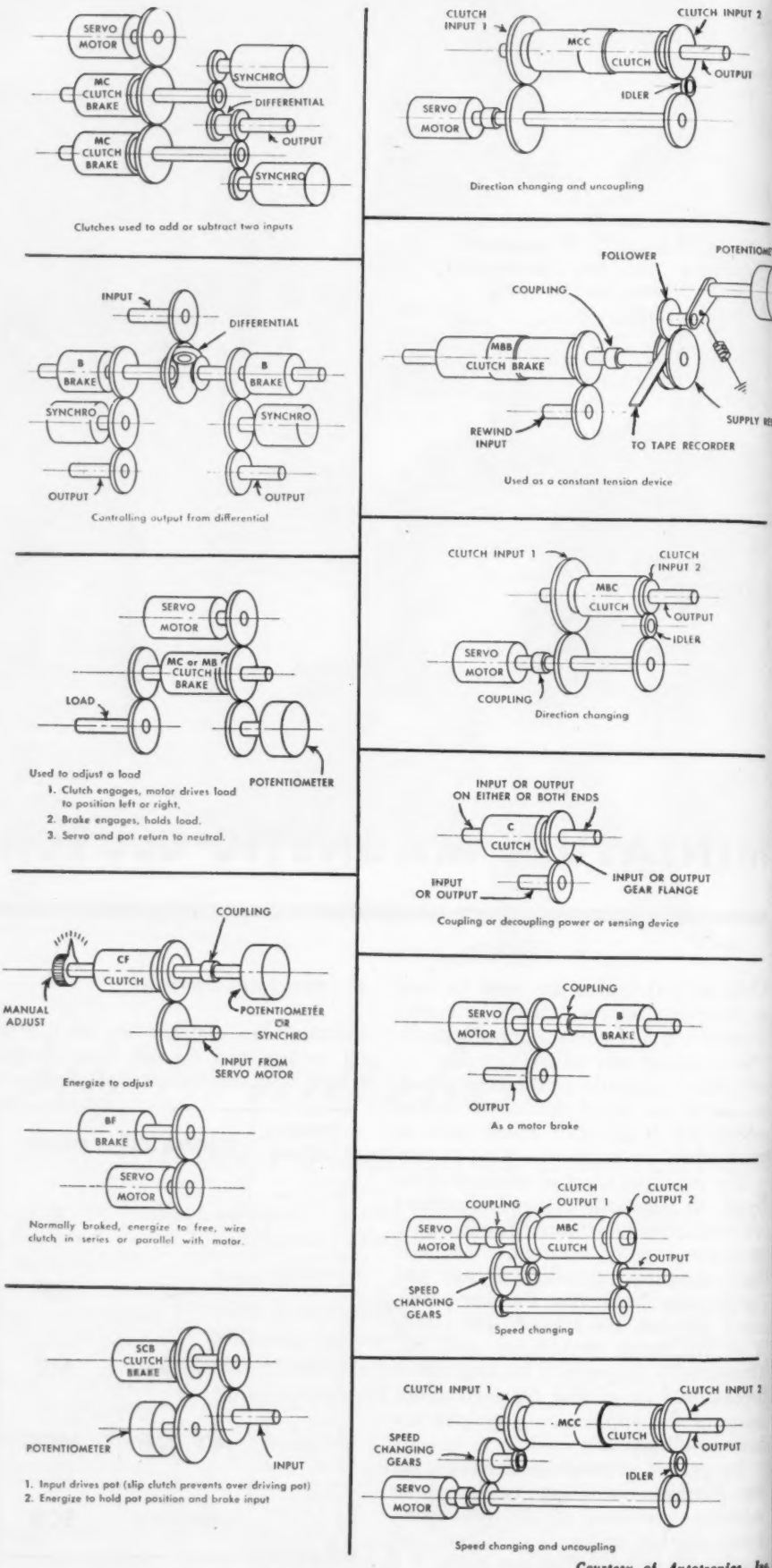
gous to a switch, performing the same function with mechanical shafts as a switch does in electrical circuits. And similarly, there are a great variety of types from which a suitable choice may be made to suit a specific application. Fig. 2 shows the principal types together with sketches of the characteristic torque versus voltage curves. These are tabulated by Autotronics, Inc., who manufacture an unusually complete line of miniature types. Fig. 3 illustrates the more important applications of these devices. Their versatility has made clutches and clutch brakes major components in complex electromechanical systems.

PRINCIPLES OF OPERATION

The clutch and the clutch brake operate in a manner similar to a solenoid. Visualize the input shaft and the output shaft as being coaxial, with a separation between them and with a fixed magnetic cylinder attached to the end of the input shaft facing the output shaft. The output shaft has a similar opposing cylinder which is free to slide axially along the output shaft, but which cannot rotate with respect to the output shaft. Thus, these two cylinders face one another, one of which is free to move in an axial direction and contact the other. Under the action of an applied d-c magnetic field, the movable cylinder is displaced axially to make a strong physical contact with the fixed cylinder on the opposing shaft developing the required locking action up to the specified torque limits. Upon removal of the d-c signal, a spring forces the movable cylinder away from its position of contact with the opposing shaft and opens the coupling. The magnetic field must be sufficient to overcome this spring force and at the same time, yield good firm coupling between the clutching surfaces.

In the clutch brake, the action of the spring forces the movable cylinder into contact with an opposing braking surface on the frame of the device, which locks the shaft to the frame within the specified limits of torque. Fig. 4 shows the balance of forces in a typical magnetic clutch as described by PIC Design Corp.

It is clear that coupling is essentially on-off, with no response until the applied magnetic field is strong enough to overcome the spring force. With sufficient field strength, the movable slug slides in a snap action until it



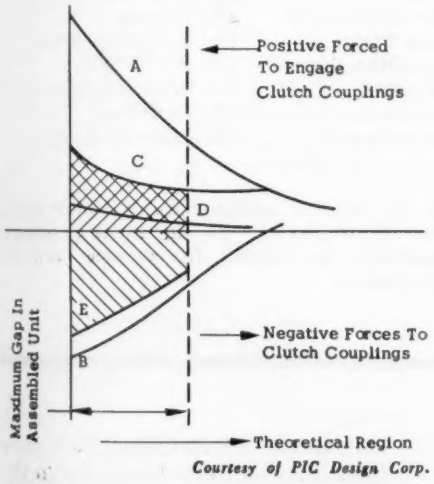
Courtesy of Autotronics, Inc.

Fig. 3 Application schematics of clutch-brake devices. Note: Units are identified by letters defined on Fig. 2.

makes the required coupling. Due to the very small airgap that results when contact has been established, a high locking torque is developed which is maintained even when the d-c field is reduced considerably below that required to initiate locking. The spring must be strong enough to break the locking action maintained by residual magnetism when the d-c field has been reduced sufficiently. In a poorly designed unit, the residual magnetism may be sufficient to maintain coupling even in the absence of any field. The proper selection of magnetic materials and the adjustment of spring constants and airgap are important design considerations.

In the clutch brake, the problem is especially severe since the spring must not only be sufficient to open the clutch, but also must be powerful enough to supply the required braking-torque. This reduces available clutching torque as shown in the interesting curves of a Globe clutch brake, Fig. 5.

The above description may be somewhat clarified by reference to Fig. 6 showing the details of construction of specific designs by Fae Instrument Corp. Since the variety of types is so great, including not only the basic units of Fig. 2 but also specialized construction features such as the concentric shaft unit of Fig. 6(b), the Fae units must be regarded merely as typical rather than descriptive of all types.



Courtesy of PIC Design Corp.

Fig. 4 Forces within the clutch as a function of gap spacing between the clutch surfaces. Motion cannot take place in the "theoretical region," but curves are shown just for clarity. (a) Variation of magnetic pull with rated applied voltage. (b) Spring force, opposing magnetic pull. (c) Resultant force tending to lock clutch. (d) Residual force with clutch de-energized. (e) Resultant force tending to open clutch. This diagram permits easy visualization of important design parameters.

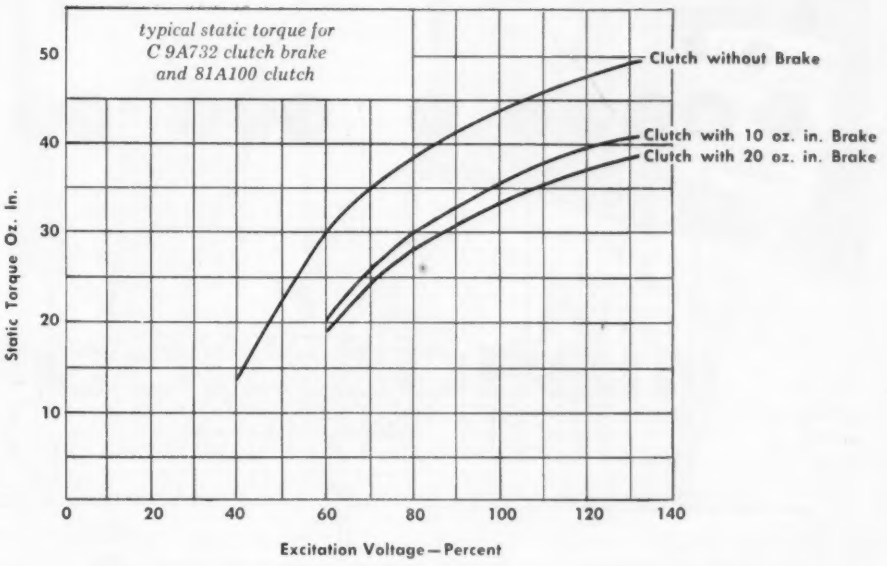


Fig. 5 Curves comparing the static torque of a clutch brake and a clutch, by Globe Industries, Inc.

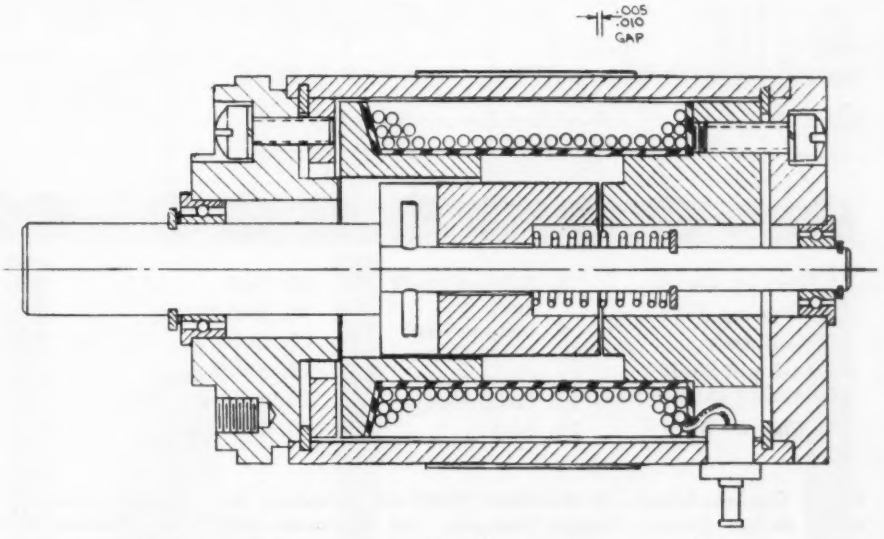


Fig. 6a Magnetic brake by Fae Instrument Corporation.

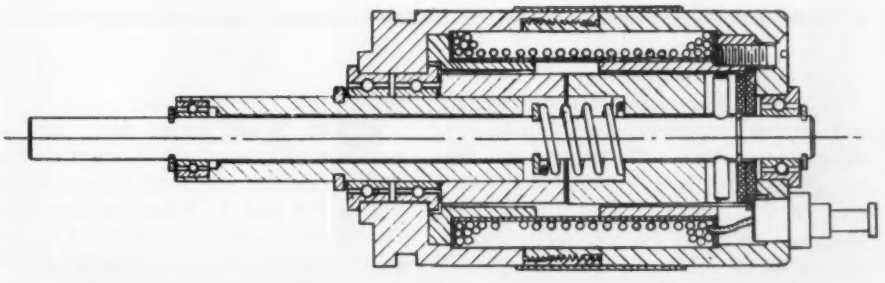
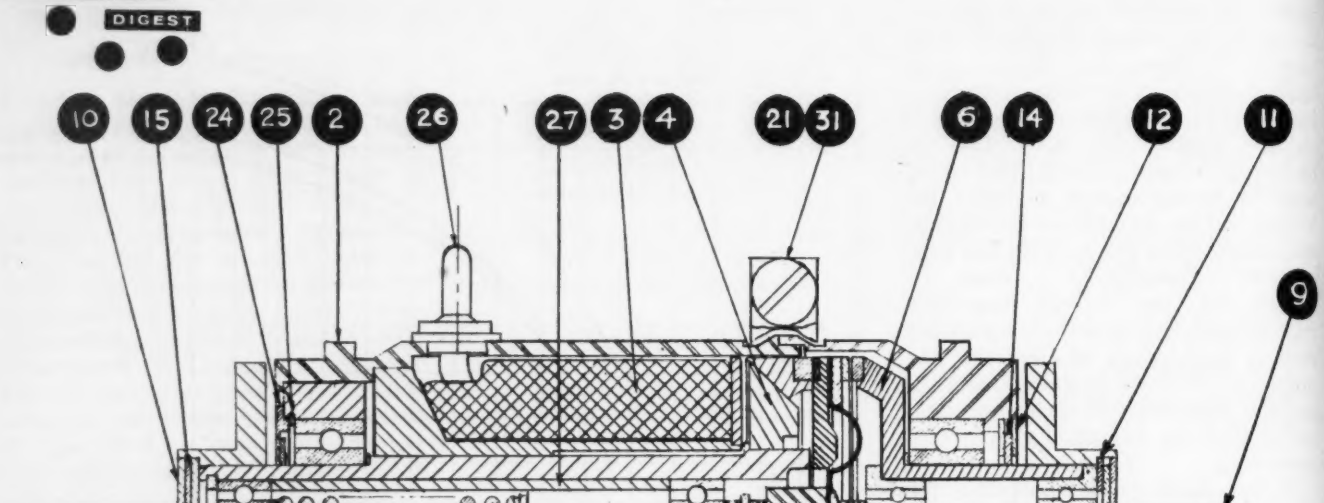


Fig. 6b Concentric shaft magnetic clutch brake by Fae Instrument Corp.

COMPONENTS DIGEST



1. Duplex Clutch
2. Housing Ass'y
3. Coil Ass'y
4. A-Input Shaft Ass'y
5. Clapper Ass'y
6. B-Input Shaft Ass'y
9. Output Shaft
10. Cover Seal
11. Cover Seal
12. Cover Seal
14. Seal
15. Seal
16. Coil Spring
17. Shim
18. Shim
19. Spacer
20. Bearing
21. Clamp
22. Bearing Flanged
23. Name Plate
24. Cover-Housing
25. Snap Ring
26. Terminal
27. Spacer-Input
28. Hub Gear
29. Bearing
30. Retaining Ring
31. #1-72¼ Fillister Hd. Scr.
32. End Cap
33. Crescent Ring

Fig. 7 Duplex Clutch by Guidance Controls, revealing internal design feature. Design Features: (a) Minimum wattage requirements mean low heat rise. (b) Location of friction materials near outer periphery means high torque and large contact areas. (c) Radical rather than axial air gaps, eliminating excessive clutch loading on the main bearings. (d) Six-legged diaphragm type spring for greater load capacity and reduced stresses.

Fig. 6(a) shows a brake unit where the applied magnetic field causes the moving armature, 20, to engage the stationary armature against the pressure of the return spring, 10, locking the shaft assembly 16. Fig. 6(b) shows a concentric shaft clutch-brake, particularly suitable for servomechanism packages where the unit is conveniently mounted on a jig-bored plate along with other major rotating components, and coupling is effected through spur-gearing. Mechanical tolerances must all be compatible with precision servomechanism requirements.

In Fig. 6, the inner shaft, 1, may couple the outer shaft, 2, in the energized condition through the armature elements 4 and 5. When unenergized, the armature element 5 is faced by the spring against the braking surface, 18, locking shaft 1.

Fig. 7 shows the internal construction of a duplex clutch by Guidance Controls illustrating important design features. Many of these features are found in comparable models by Dynamic Instrument Corp.

Guidance Controls Corp. offers some helpful hints on the internal design details. They recommend the use of pure Armco iron for high permeability, high saturation density, and low residual flux. Ordinary cold-rolled carbon steels do not compare in these characteristics. (Actually the low resistivity of pure iron results in a slight time lag in the build up of flux, due to transient Eddy currents. A more serious deficiency is the poor corrosion resistance of pure iron, requiring a good protective finish.)

Guidance Controls recommends 303 stainless steel for the non-magnetic portions of the internal structure, for good strength characteristics and the matching of temperature coefficients of structural parts, magnetic elements, and bearings. This is almost essential for units designed for operation over a high temperature range where the differential expansion of steel vs. aluminum introduces excessive errors in geometry. Sintered porous metal parts are recommended as friction materials for low wear and long reliable life.

Internal springs must be designed to maintain properties over the range of temperature, without fatigue stresses, to guarantee zero backlash over the life of the unit. Complex manufacturing and heat treating processes are required. Temperature stabilization is used to insure uniformity in dimensional and performance characteristics.

CLUTCH APPLICATION FACTORS

The biggest single application difficulty of friction-disc clutch and clutch brake devices is the reliability of contact characteristics. Contact surfaces may be of the metal-to-metal variety, or non-metallic materials such as cork or silicone rubber may be used. The application engineer must specify very precisely what the actual life requirements are. For example, *are the opposing contact surfaces rotating at high relative angular velocities at the instance of engagement?* Significant inertial energy involved in starting and stopping will accentuate wear. Some companies such as Dynamic Instrument Corp. check life with *full rated torque applied during starting and stopping*, a particularly severe test condition. If a clutch drives a limited motion device such as a resistance potentiometer with limit stops, the ability of the clutch to withstand slipping when the potentiometer is against the stops

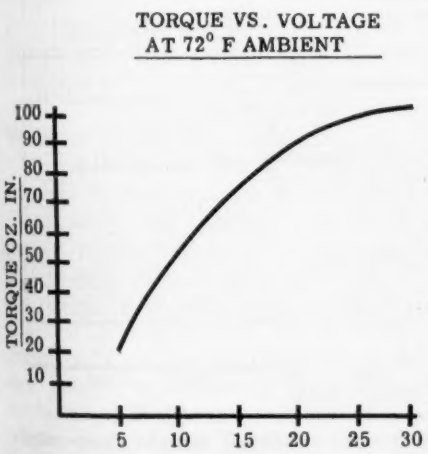


Fig. 8a Applied DC Voltage
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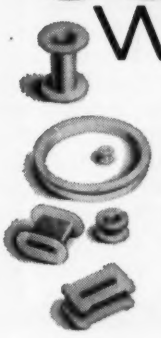

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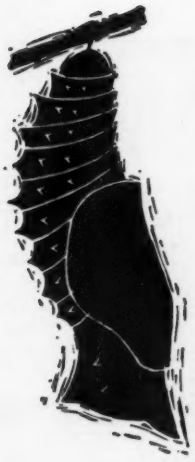

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must be verified. Heat dissipation and wear under these conditions may be extremely high. High ambient temperatures introduce not only their usual difficulties with insulation lubrication and mis-matched coefficients of expansion, but also can adversely affect the properties of many clutching materials. For this reason, metals are often preferred.

Frequently, some sort of "running in" is required to guarantee a uniform torque characteristic. This may consist of slipping the engaged surfaces a specified number of times until a leveling off occurs in the torque characteristics. A sufficient design margin must be available to account for variations during life and from unit to unit. It is in the area of clutch surface materials and their treatment as well as "adjustment" procedures that most manufacturers have their individual shop secrets. Fae Instrument discusses this phase of clutch design in the following paragraphs:

"The smooth friction faces allow slippages when rated torque is exceeded (useful when driving pots with internal stops). This type of clutch face also prevents indexing during engagement and disengagement (as compared with crown-tooth devices). Traces of contamination on friction faces result in torque reduction. Wear on friction faces result in torque reduction. Wear on friction faces is minimized by special surface hardening methods such as "Skottsonizing" and in some instances several thousandths of an inch case hardening. Hardchroming of wear surfaces further adds to the wearability as well as corrosion proofing.

"Life is not an easy term to define due to non-constant environmental conditions and required duty cycles. However, life on all units should be at least one million cycles at no load, zero speed, room conditions.

"Principal limits to clutch reliability are bearing failures under severe environments. Contamination in spite of bearing shielding is unavoidable. Condensation of moisture under humidity conditions can cause some small fall off in torque, especially on friction brake surfaces of clutch-brake combinations.

This should be compensated for by conservative performance ratings allowing for the losses. Good internal shielding, rugged plating, non-oxiding brake surfaces all contribute to proper design for severe environments."

Dynamics Instrument Corporation remarks that life tests are conducted *periodically* on their units *at rated load and speed*, for a guaranteed minimum life. They guarantee $3x10^6$ cycles under 60% of full torque load.

Clutch friction generally exceeds that due to bearings alone due to the heavy internally developed magnetic forces required for the functioning of the unit. Some clutch designs impose heavy thrust loads on the bearings which sharply increase friction and reduce life at high speed. For this

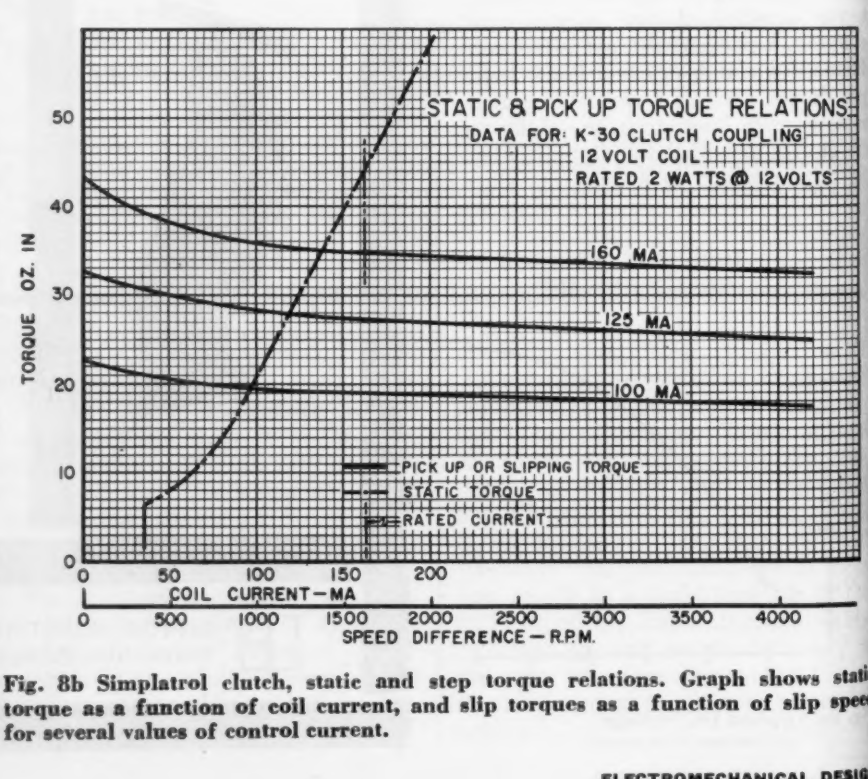


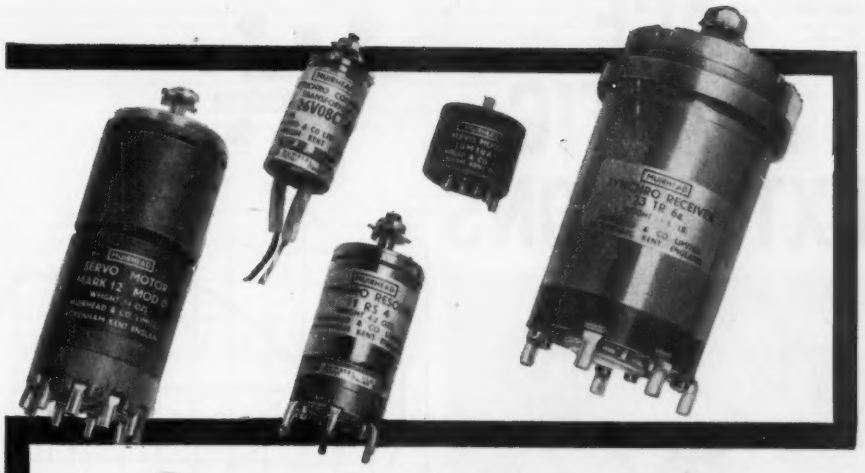
Fig. 8b Simplatrol clutch, static and step torque relations. Graph shows static torque as a function of coil current, and slip torques as a function of slip speed for several values of control current.

reason, no-load friction (with no externally applied shaft torques) may be specified separately for the energized and unergized states. Dynamic Instrument Corp. and Guidance Controls have designs where bearing loads are minimized by having only radially directed magnetic forces between moving members and the frame. These radial forces balance out to avoid thrusts on the bearings. However, the inertias of these units are somewhat higher than other designs. The applied voltage rating for magnetic clutching devices is easily varied over a wide range by choosing a suitable winding for the excitation coil. As long as the total copper volume of the coil remains constant, the power ratings are unchanged. However, the rated applied voltage is proportional to the number of turns, which in turn depends upon the wire size. The principal limitation is the fineness of wire which can be economically wound, which sets the upper voltage limit in miniature components where available wire room is limited.

Since magnetically actuated devices depend upon ampere-turns, it is apparent that response will diminish at high temperature where the increased winding resistance reduces current and power in accordance with Ohm's law. There must be sufficient allowance for this, as well as the usual concern over the ability of the insulation to withstand the ambient temperature plus internal temperature rise.

Voltage variations in the energizing supply likewise affect the available ampere-turns in the clutch coil. Fig. 8 (a) shows a typical torque versus applied d-c voltage characteristic. Note that in the region above approximately 20 volts little change in torque takes place. This indicates a saturated condition in the magnetic circuit, which renders the device relatively insensitive to small changes in ampere-turns such as might result from temperatures or voltage variations. Torque specifications should be met at minimum rated voltage and maximum rated ambient temperature with winding temperature rise added.

Fig. 8(b) shows the static as well as the slipping torque characteristics of a Simplatrol clutch. The actual power requirements of the magnetic clutch depend upon the efficiency of the magnetic circuit as well as the mechanical design factors. While design details will not be considered here to any extent, it should be pointed out that clutch design is a matter of extensive compromise. Small air gaps required for high efficiency result in excessive residual magnetism which



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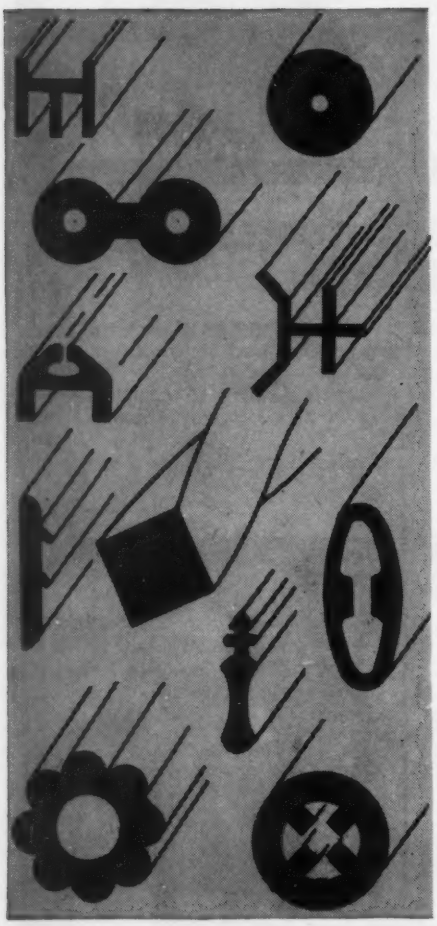

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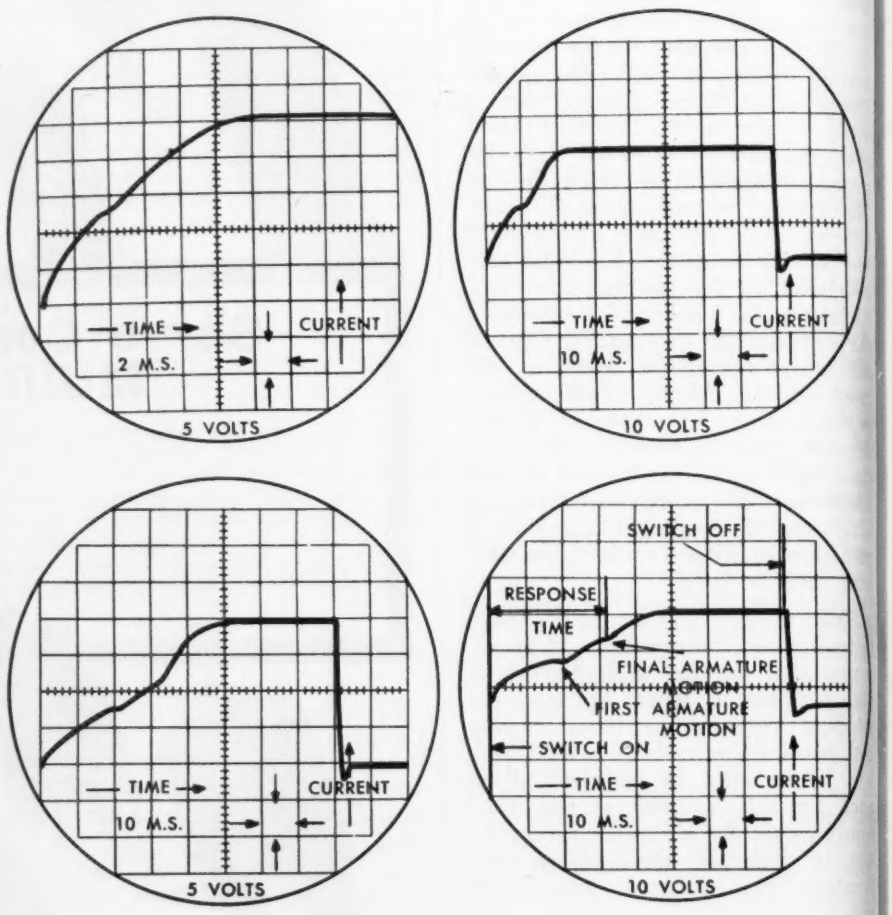


Courtesy of Autotronics, Inc.

Fig. 9 Typical Oscilloscope, response readings.

means strong return springs and consequent loss of available torque. The best magnetic materials do not exhibit good mechanical or corrosion resistant properties, and so forth. While required clutch power is generally not critical, it should not be excessive, nor introduce a high temperature rise.

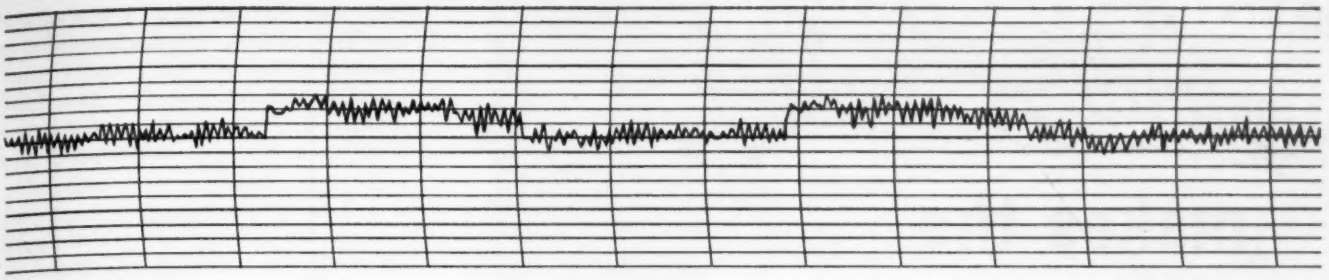
In many applications speed of clutch response is a key design characteristic. This is certainly true where a clutch is used as the actuation element of a closed loop control system, but it is also of importance in many high speed clutch systems.

The major factors affecting time delay are the lag in current build up in the inductive clutch coil, and the delay in the response of the moving armature due to its inertia. The force of the restoring spring opposes the applied magnetic force, and further serves to delay the response, but nothing can be improved here since a stiff restoring spring (plus a minimum of residual magnetism) is essential to a fast disengagement.

Unfortunately, as in all electro-magnetic devices, the requirements of high speed and high efficiency are incompatible. Current build up lag corresponds to the conventional L/R time constant.

Increasing efficiency by closing magnetic gaps or packing more copper into the energizing coil means a longer time constant. Adding a large resistor in series with the coil and exciting from a high voltage supply will increase speed at the expense of the power lost in the series resistor. A parallel R-C network in series with the coil may speed up response somewhat more efficiently by passing a high initial current through the uncharged capacitor. Other techniques applicable from magnetic amplifier theory are also feasible.

Where possible, constant current source energization may be available. Vacuum tube circuits employing a pentode output or current feedback



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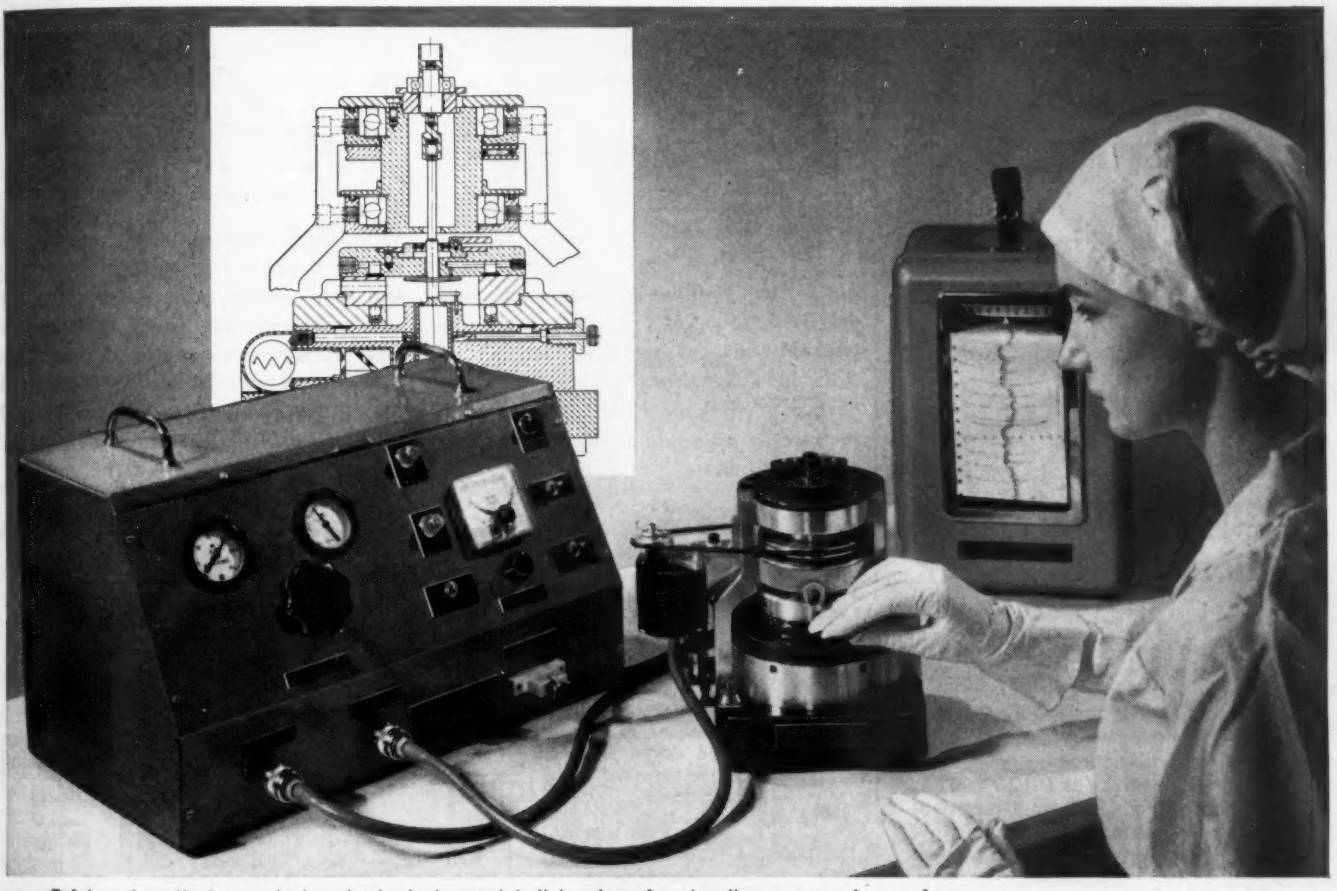

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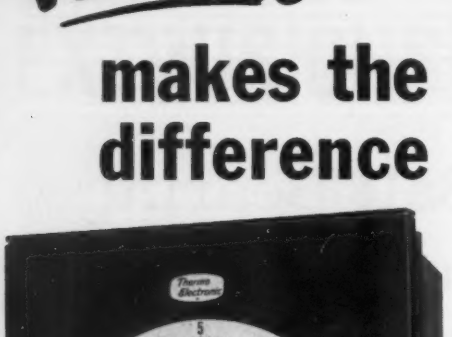

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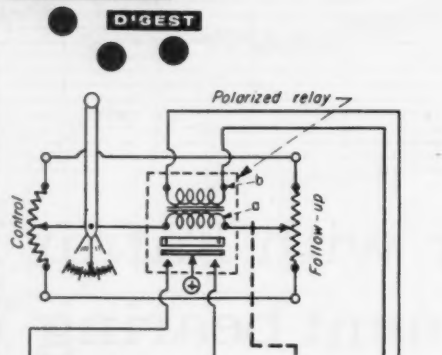

Fig. 10a Follower servomechanism driven by a relay operated clutch system. The use of velocity feedback results in a continuous high frequency chatter around the closed loop that effectively averages out the nonlinearity of the clutch.

Fig. 10b Comparison of system response using a servo-clutch and a typical servo motor. The clutch drive unit is capable of five times the acceleration of the servo motor. Taken from Stuelpnagel and Dallas, "Off-On Modulated Reversing Clutch Servo," AIEE Applications and Industry, January, 1953.

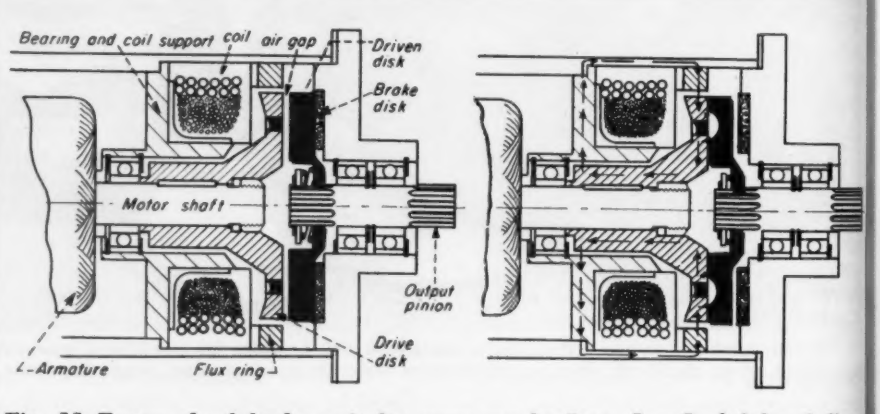

Fig. 11 Fastop clutch-brake unit for servo use by Lear, Inc. In left-hand figure the clutch is de-energized and the load is coupled to the brake. The motor is disconnected and coasts to a halt at will. The right hand figure shows the clutch energized so that the motor drives the load.

may approximate such a source. Under this condition, the principal lag occurs in the response of the armature whose inertia and total travel may be minimized by careful design. Unlike constant voltage conditions, the constant current source may not be able to speed up response by overdriving (where heating and duty cycle permit) if the magnetic circuit is already saturated.

The time delay in clutch response is not measureable as readily as other parameters. In the clutch design phase where parts may be adapted to the measurement problem a variety of techniques may be employed based upon opening of carefully set contacts by the clutch motion, and R-C timing circuits.

Special methods have been devised based upon the clicking noise indicat-

ing the instant of impact of the armature members. The method described by Autotronics shown in Fig. 9 is particularly convenient for testing finished clutches since it only required external measurements using standard laboratory instruments.

Definitions of response time may differ among manufacturers and it is important for the user to be sure of his terms. The following comments on response time by Fae Instrument Corp. should be compared with those of Autotronics in Fig. 9. "Response time is defined as the time element measured in milliseconds, that the two uncoupled shaft couplings require to couple and transmit the rated torque from the instant the stationary field coil circuit is completed at rated voltage. This response time can be kept to a minimum by using a minimum mass sliding coupling, minimum friction through fine micro finishes on sliding surfaces, minimum return spring tensions and most important minimum air gaps between the engaging surfaces. The user should not attempt to work to the minimum torque ratings and keep to the maximum allowable voltage for the specific clutch in order to minimize response time. "Response time can be checked through an oscilloscope response pattern by driving an unenergized clutch at constant speed coupled to a transducer. The clutch field is energized and the transducer triggered at the same instant. The scope pattern will disclose the magnetic field and current build up until current stability and saturation is reached. The resulting curve can be calibrated to disclose within at least a millisecond the response time characteristics."

THE CLUTCH AS AN ACTUATOR

In addition to the previously described clutch applications, magnetic clutches are sometimes used as actuator elements in regulating and control systems. They are particularly useful for applications involving high intermittent overloads, or when extremely rapid time response (better than 5 msec.) is required, faster than obtainable in conventional electric servomotors. Because of the relative complexity of a bi-directional clutch system as compared with a common servomotor, this type of clutch application is most economical where several hundred watts of power must be controlled, particularly if control is required for high peak loads. Here the relatively low control power required for clutch actuation provides real power supply economy making for a much simpler and more reliable con-

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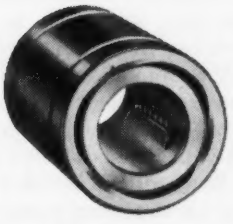

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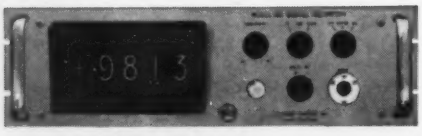

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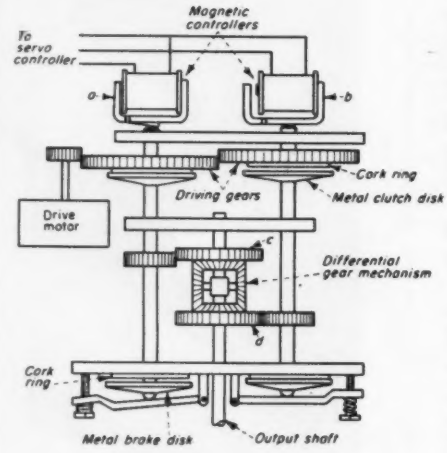


Fig. 12 Detailed schematic of a clutch type instrument servo manufactured by Norden. This system incorporates simultaneous clutching and braking. In the diagram, magnetic controller a is energized. This engages the clutch from the driving motor and disengages the brake for the left hand shaft, by axially shifting the shaft. Thus the output shaft is being driven by the left hand shaft through differential gear c. Since only one controller can be energized at a time, the right hand shaft is held stationary by its brake. This means that gear d is locked so that the differential can be driven through gear c. This arrangement permits rapid starting and stopping.

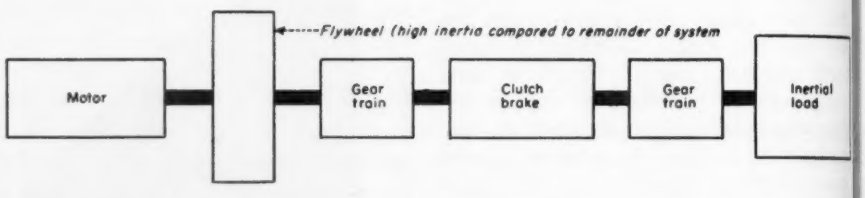


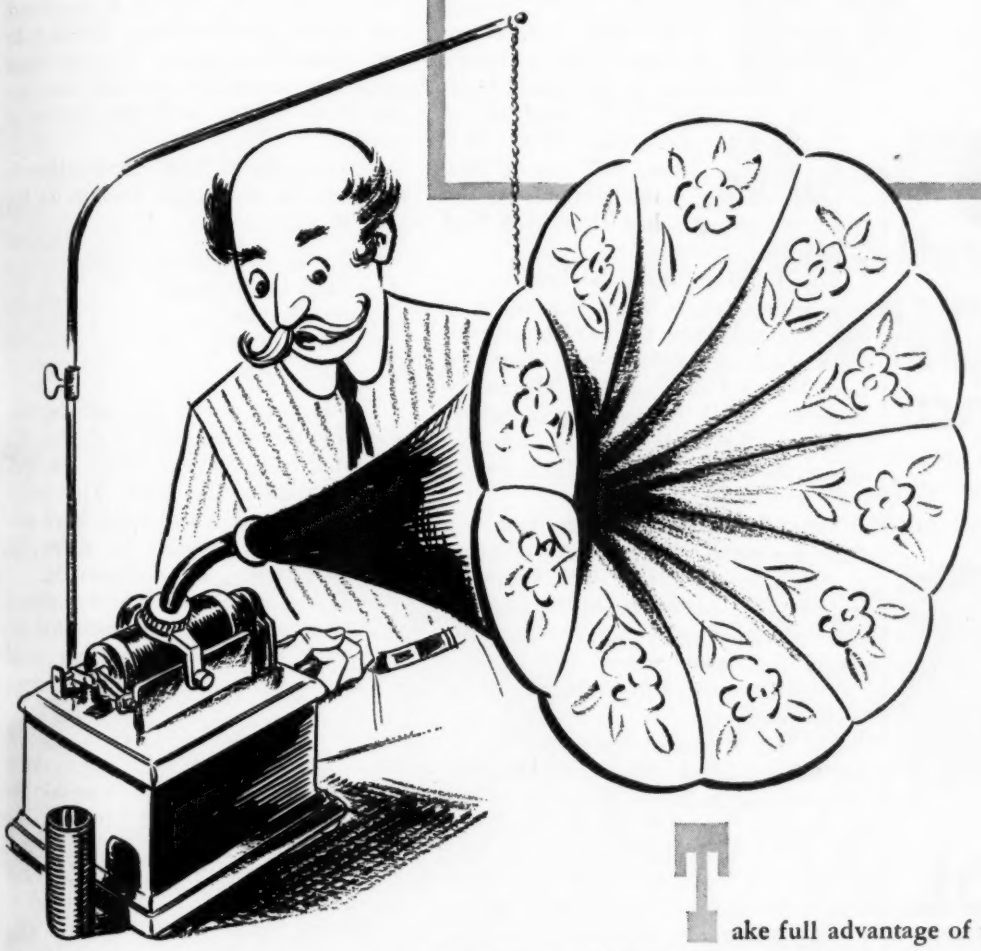
Fig. 13 Schematic of system that is useful for rapid starting and stopping. When the clutch is energized, the load is coupled to the high inertia flywheel and motor. This results in high load accelerations. When the clutch is deenergized, the load is disconnected from the flywheel and motor and is coupled to the brake. The brake brings it to a rapid stop. The flywheel supplies pickup energy during acceleration.

Courtesy of the Norden Co.

trol amplifier. This feature is somewhat less important in this age of transistors than it was when relatively bulky vacuum tube amplifiers drawing heavy quiescient power were required. The clutch servo's ability to supply peak loads from energy stored in a flywheel is a decided advantage in reducing maximum power supply drain. A good discussion of the clutch as a servo-actuator, plus a detailed comparison of different clutch types is provided in Truxal's "Control Engineer's Handbook", McGraw-Hill, 1958. For slow tracking, the on-off type of clutch servo is suitable to a degree but the continuous dithering as the error moves in and out of the actuation limits seriously limits life. (Occasional remote positioning with relatively long quiescient periods between is a suitable application.) "Hysteresis", or the difference between on and off voltages may provide a serious loop stability problem which is not easily solved by linear techniques. This problem is best overcome by means of an on-off energization device at the clutch input so that the clutch is only energized at rated voltage, or zero. The hysteresis problem is then transferred to the energization device. A relay, for example, exhibits appreciable hysteresis, although less than a clutch; see Fig. 10. Solid state circuits have been devised where this hysteresis is negligible.

A simple but extremely effective application of a friction clutch-brake is illustrated in Fig. 11. Here the actuator motor may be designed for highest running efficiency, even at the price of substantial motor inertia. When the clutch is energized, the high inertia rotor at full speed is coupled to the load providing a load acceleration equal to the ratio of maximum clutching torque (minus load friction) to load inertia. Since the motor is already up to speed no particular energy

Now hear this!



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COMPONENTS DIGEST

is required for its acceleration. Actually, some of the motor's inertial energy is transferred to the load with a momentary loss in motor speed. Motor speed fluctuations during peak loads may be minimized by the addition of a flywheel to the motor shaft. This extra energy "reservoir" means that a much smaller motor, capable of delivering average rather than peak load power is suitable.

Fig. 11 also shows the braking action which occurs when the motor is de-energized. Here the load is coupled to a braking surface providing extremely rapid deceleration. The motor armature itself is disengaged, which means the brake does not have to dissipate the energy of this high inertia member.

Fig. 12 shows a more general version of a servo actuator drive utilizing a clutch-brake. While this figure illustrates the action in easily visualizable form, a more convenient assembly would be based upon the use of standard commercially-available clutch-brake packages.

Fig. 13 illustrates the principles of Fig. 11 in block diagram form. The selection of suitable gear trains optimizes the "matching" between motor and clutch and clutch and load. The inertias of the rotating clutch members become significant in carrying out this optimizing.

Consider Fig. 13 during clutching. The following criteria determine the choice of gear ratios and drive motor:

- Clutch torque multiplied by the second train ratio must be sufficient to drive the load,
- The over all reduction ratio multiplied by motor speed must correspond to required load speed,
- For maximum acceleration, the second gear ratio must equate the inertia of the clutch output member to the inertia of the load. If the load includes viscous friction as well as inertia, requiring torque for both velocity and acceleration, the second reduction ratio is:

$$(J_c \times \alpha_L)^{1/2}/F_L + J_L\alpha_L)^{1/2}$$

J_c = clutch output inertia
α_L = load acceleration
F_L = load friction torque at rated speed
J_L = load inertia

Effectively these are the same selection factors used in matching a conventional servomotor to its load through suitable gearing.

A figure of merit for clutches analogous to that for motors is maximum transmitted no-slip torque divided by output-member inertia. For optimum ratio the maximum possible load acceleration is one half this figure of merit.

The maximum load acceleration in the absence of viscous friction in the load is:

$$\alpha L = T_c/2\,(J_c \times J_L)^{1/2}$$

αL = load acceleration
T_c = clutch torque
J_c = clutch inertia
J_L = load inertia

The average power that can be supplied by the prime mover during the estimated duty cycle must be sufficient to drive the load. The prime mover and its flywheel must have sufficient reserve capacity to drive the load during peak-demand periods.

The inertia of the prime mover and its flywheel plus the reflected inertia of the input clutch member, must be large compared with clutch output inertia.

Note that the dissipation in the clutch for a given load duty cycle is independent of the way in which the over-all ratio is divided between the two gear trains.

Also note that the power dissipated in a clutch during the acceleration of an inertial load *equals* the final kinetic energy of the load, regardless of ratios!

TABLE 1

Response To Different Forms of a-c Energization

Times listed below are in seconds

	SIZE OF UNIT			
Excitation	20	30	40	5
Unfiltered full-wave rectified direct current	.010	.012	.014	.02
Capacitor filtered full-wave	.007	.010	.011	.01
Capacitor aided initial over-voltage	.005	.006	.008	.01

Reaction times shown are the elapsed times required between switch closure and intimate contact of torque-producing faces. All values are average of times recorded by testing with an oscilloscope. Deviations above and below the listed times can be expected.

All tests were made using normal rated excitation except when recording capacitor-aided response, where initial voltage and current are high but reduce to normal after capacitor discharge.

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Now ASCOP has taken the same unique magnetic readout principle and incorporated it into a neatly miniature, ruggedly simple design to read out shaft positions to one part in 2^{13}. Parallel output is in binary code and total count is reached after 64 turns of the precision shaft and gearing. Lead-lag head arrangements assure that external decision making circuitry is minimized. The new ASCOP encoder operates in either direction and can be read out at rest or on-the-fly at speeds up to 10,000 rpm with equal facility. Since the only contacting parts are shaft and gearing, these are the only factors affecting life.

Condensed Specifications

Total Count: 2^{13} achieved in 64 turns of input shaft
Size: ..... 2¼" dia. x 3⅛"
Code: ..... Binary with lead-lag heads
Output: ..... Parallel
Weight: ..... 16 ozs.
Inertia: ..... 70 gm-cm²
Breakaway Torque: ..... 0.05 in. oz.
Max. RPM: ..... 10,000 rpm
Expected Life: 20,000 hrs. at 4000 rpm (expected bearing and gear life)

Brochure, price and applications notes on request

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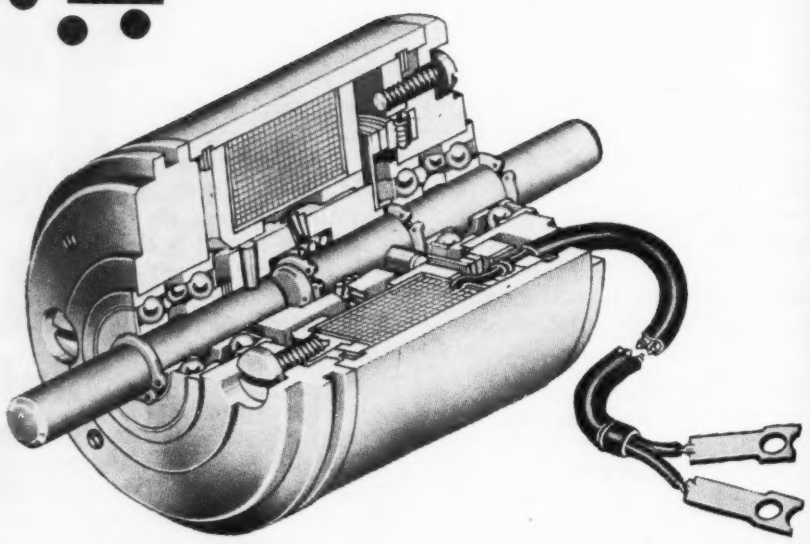

Fig. 14 Reeves magnetic clutch illustrating crown tooth construction.

MISCELLANEOUS CONSIDERATIONS

Crown-tooth construction, Fig. 14, pioneered by Reeves Instrument Corp. provides very high locking torque between clutch surfaces and is therefore useful where a high load must be driven without slip. Essentially the opposing clutch faces engage on a toothed surface.

This type clutch requires case-hardening to withstand the impact of engagement, but ductility under the surface to permit slight deflections. A certain amount of indexing during engagement is unavoidable. Corrosion protection is necessary as with comparable clutching devices. Crown-tooth clutches are definitely *not* recommended for slip applications.

Servomechanism mechanical factors: Because clutches are usually incorporated in precision gear trains, they are required to have mechanical tolerances consistent with gearing accuracies. These tolerances relate to squareness of shaft with mounting surface, shaft run-out, radial play in bearings, and concentricities. Synchromount construction is relatively standard. Zero backlash between engaging clutch shafts is usually specified for highest accuracy and to avoid closed loop instabilities. Clutch friction provides additional torque loading which may contribute to servo starting friction especially at low temperature where lubricant viscosity increases. While a measure of safety is provided by the ability of the clutch to slip under excessive load (should the low speed end of the gear train jam up), it is not recommended for this function, and separate friction clutches should be used. The settings of the friction clutches and their location in the gear train must be compatible with the drive clutch settings, so that the friction slip clutch always slips first. Sometimes in sensitive miniature servomechanisms where a fair amount of load friction is present (such as from a 10-turn potentiometer driven at high speeds) the location and setting of drive clutch and slip clutch become complex problems. This is accentuated by the wide spread in slip torque over the environmental range and during the life of the slip clutch, particularly at low torque settings.

The inertias of the clutch members must be figured in high acceleration servomechanisms. In many applications the clutch is driven at high speed. Clutches may be used as speed changers in "multiple-mode" servomechanisms where very high slew speed may be required, together with slow tracking speed. (Bowmar Instrument and lately other manufacturers have devised miniature precision gearheads with built in clutch-type gear changers. However, these useful devices are still quite costly.

There is one precaution to be taken in designing two-speed systems, namely that gearing should not be driven backward. Since this possibility does not normally occur, it may be overlooked by the gear train designer.

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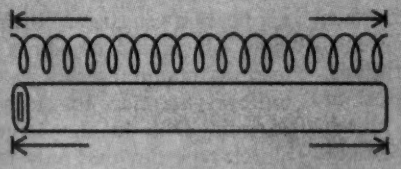

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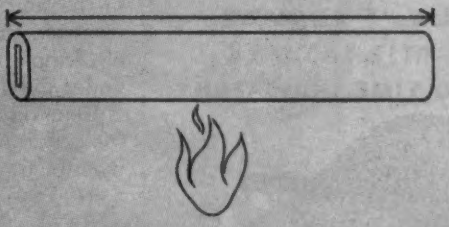

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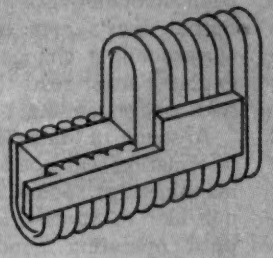

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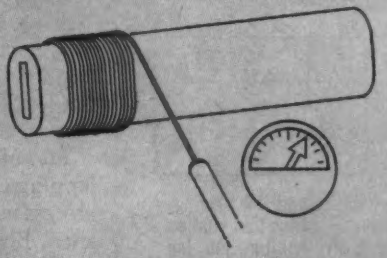

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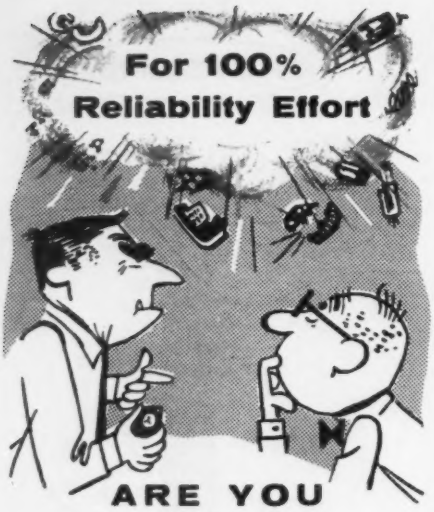

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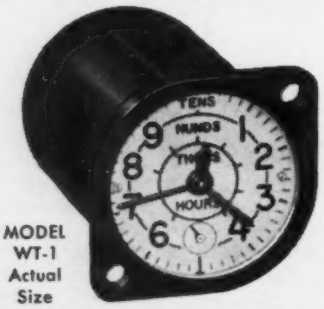

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COMPONENTS DIGEST

Specifically, there are certain arrangements of two speed gearing using a duplex clutch where some gear meshes may be driven backward so that an uncoupled clutch member is driven at high speed, leading to high friction and inertia. This problem is avoided by inspection of possible solutions.

With respect to environment, clutch type devices generally can meet specifications comparable to other rotating components of the servomechanism.

A-c excitation: Magnetic clutches may be energized on a-c through suitable rectifier circuitry. The major difficulty encountered in high speed low line frequency applications is dither resulting from the pulsating character of the rectified current, although some smoothing is provided by coil inductance.

Unfortunately, filtering circuits introduce time delays which must be added to those already occurring within the unit. Table I shows variation in response time for some standard sizes of Simplatrol a-c energized clutches under different energization conditions.

Remarks On Questionnaire: Most of the information received from clutch manufacturers based on a questionnaire sent out by ELECTROMECHANICAL DESIGN, has been incorporated in the preceding text. This section contains additional detailed remarks.

Major performance problems are related to maximizing output torque, according to Reeves Instrument Corp., Warner Electric Brake and Clutch Co., manufacturers of commercial clutches designed for appreciable slipping regards the dissipation of heat as the biggest problem.

Manufacturers generally agree that lapping, surface treating, and plating are essential to reliable clutch performance. Shielding from anti-friction contaminants such as oil is essential.

Reeves points out that temperature and humidity relating to viscosity of lubricants and expansion coefficients are primary environmental problems.

Warner Electric avoids specifying life because of the extreme variety of potential applications in industry. They do have favorable customer reaction in the field.

Guidance Controls Corp. provided information on mechanical design problems and their solution. They listed fastening problems associated with the springs as most complex. Staking, cementing, and riveting are involved.

Dynamic Instrument Corporation listed initial design problems in achieving their low breakaway (drag) torques and high output torques. The solution was found by designing their units so as to introduce the magnetic flux both axially and radially thereby reducing the magnetic thrust loads on the bearings which resulted in low breakaway torques and long reliable life.

In the Guidance Controls design, the magnetic path was "insulated" from the bearings when early experiences revealed electrolytic corrosion resulting from voltages generated by the balls rotating in a magnetic field.

MASTER CHARTS

Miniature Precision Magnetic Clutches And Brakes And Related Devices-The Master Charts on the following sheets are intended to provide the application engineer with an overall view of what's available. Data from leading manufacturers is tabulated in uniform notation for convenient comparison. Due to the large variety of clutch-type devices, only representative information is provided. The manufacturers should be consulted directly in finalizing a component selection.

In the interests of simplicity certain compromises in presentation have been required. Overly specialized data has been omitted. Some redundancy in the original catalog material has been avoided. Frequently input and output shafts may be reversed, with corresponding changes in ratings. The engineer must read the tabulated data with understanding.

Absence of data indicates that this information was not available from the manufacturer. Some manufacturers do not like to specify *life*, for example, until operating conditions are completely known. Other difficulties arise from differences in definition or measurement of certain items such as time constant, or even length. For these reasons, use these tables only to get a good start.

As mentioned in the introduction, we are restricting these tables to miniature precision friction disc clutches with stationary coils such as are used in servomechanisms and complex electromechanical assemblies.

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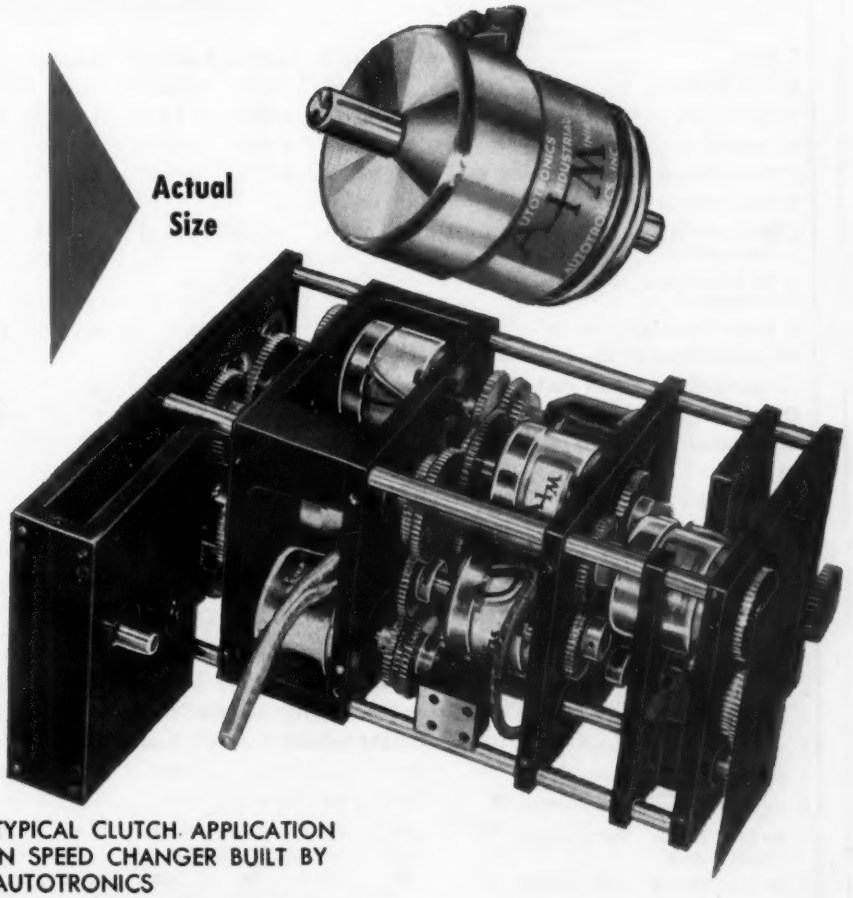
  - C-125-Clutch-64 oz. in.
  - BF-125-Brake Free-40 oz. in.
  - MC-125-Brake-32 oz. in. Clutch-48 oz. in.



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CIRCLE NO. 61 ON INQUIRY CARD

Summary of Physical and Performance Characteristics of Clutches and Brakes

AUTOTRONICS, INC.

	Units	B-4	B-6	B-8	B-10	BF-4	BF-6	BF-8	BF-10	MB-4	MB-6	MB-8	MB-10
1. Model	--												
2. Type of Device	--	Brake	Brake	Brake	Brake	Brake	Brake	Brake	Brake	Cl. Br.	Cl. Br.	Cl. Br.	Cl. Br.
3. Diameter	Inches	.594	.827	1.090	1.370	.594	.827	1.090	1.370	.594	.827	1.090	1.370
4. Length	Inches	.810	1.140	1.390	1.493	.882	1.240	1.485	1.620	.810	1.140	1.390	1.493
5. Clutch Torque	Ounce Inches	--	--	--	--	--	--	--	--	2.0-d	8.0-d	16.0-d	30.0-d
6. Brake Torque	Ounce Inches	4.0-e	16.0-e	32.0-e	60.0-e	2.0-d	8.0-d	16.0-d	30.0-d	2.0-e	8.0-e	16.0-e	30.0-e
7. No Load Torque (unenergized)	Ounce Inches	.05	.10	.15	.20	--	--	--	--	.10	.20	.50	.50
8. No Load Torque (energized)	Ounce Inches	--	--	--	--	.12	.25	.50	.50	.05	.10	.25	.25
9. Inertia (Input A)	Gm-Cm^2	.34	1.6	5.6	13.8	.68	4.0	13.3	28.3	.45	2.8	8.5	15.1
10. Inertia (Input B)	Gm-Cm^2	--	--	--	--	--	--	--	--	--	--	--	--
11. Inertia (Output)	Gm-Cm^2	--	--	--	--	--	--	--	--	.34	1.7	5.6	14.0
12. Power Input	Watts	2.5	3.5	4.0	4.5	2.5	3.5	4.0	4.5	2.5	3.5	4.0	4.5
13. Response Time	Milliseconds	4.8	9.5	27.0	32.0	6.5	8.0	27.0	32.0	5.3	11.0	27.0	35.0
14. Life	Operations	Over 10^8 cycles at 60 cps. (through MB-10)											
15. Remarks	--	Brakes when energized.				Brakes when deenergized.				Input gear flange clutch to output when deenergized. Input free, output braked to housing when energized.			

DYNAMIC INSTRUMENT CORP.

	Units	D-MC-5	D-MC-8	D-MC-11	D-MC-13	D-MC-18	D-MB-5	D-MB-8	D-MB-11	D-MB-13	D-MB-18
1. Model	--										
2. Type of Device	--	Clutch	Clutch	Clutch	Clutch	Clutch	Brake	Brake	Brake	Brake	Brake
3. Diameter	Inches	.594	.827	1.090	1.370	1.750	.594	.827	1.090	1.370	1.750
4. Length	Inches	.882	1.240	1.485	1.620	1.930	.810	1.140	1.390	1.493	1.805
5. Clutch Torque	Ounce Inches	5	25	60	120	240	--	--	--	--	--
6. Brake Torque	Ounce Inches	--	--	--	--	--	6	30	64	130	250
7. No Load Torque (unenergized)	Ounce Inches	.02/.03	.03/.05	.03/.08	.05/.10	.05/.10	.03	.05	.05	.08	.08
8. No Load Torque (energized)	Ounce Inches	.03	.05	.05	.08	.08	--	--	--	--	--
9. Inertia (Input A)	Gm-Cm^2	.21	1.05	3.5	10.6	36	.21	1.04	3.6	10.6	36.2
10. Inertia (Input B)	Gm-Cm^2	--	--	--	--	--	--	--	--	--	--
11. Inertia (Output)	Gm-Cm^2	.485	2.2	7.1	19	63	--	--	--	--	--
12. Power Input	Watts	2.5	3	3.5	4	5	2.5	3	3.5	4	5
13. Response Time	Milliseconds	5	10	28	34	40	5	10	28	34	40
14. Life	Operations	--	--	--	--	--	--	--	--	--	--
15. Remarks		Unenergized torque values for individual shafts.									

FAE INSTRUMENT CORP.

	Units	F-4	F-5	F-6	F-11	F-12	F-13	F-19	F-20	F-23	F-24	F-28
1. Model	--											
2. Type of Device	--	Brake	Brake	Brake	Cl. Br.	Cl. Br.	Cl. Br.	Clutch	Clutch	Clutch	Clutch	Brake
3. Diameter	Inches	1-1/16	1-1/16	1-1/16	1-1/16	1-1/16	1-1/16	1.75	1.75	1.75	1.75	1.75
4. Length	Inches	1-49/64	1-49/64	1-49/64	1-49/64	1-49/64	1-49/64	2-1/8	2-1/8	2-1/8	2-1/8	2-1/8
5. Clutch Torque	Ounce Inches	--	--	--	12	60	8	80	40	80	50	--
6. Brake Torque	Ounce Inches	12	35	80	8	8	16	--	--	--	--	50
7. No Load Torque (unenergized)	Ounce Inches	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
8. No Load Torque (energized)	Ounce Inches	.08	.08	.08	.08	.08	.08	.10	.10	.10	.10	--
9. Inertia (Input A)	Gm-Cm^2	2.2	2.2	2.2	2.2/5.3	2.2/5.3	2.2/5.3	9.2/25.6	9.2/25.6	9.2/25.6	9.2/25.6	9.1-d
10. Inertia (Input B)	Gm-Cm^2	--	--	--	--	--	--	--	--	--	--	--
11. Inertia (Output)	Gm-Cm^2	--	--	--	--	--	--	--	--	--	--	--
12. Power Input	Watts	3	3	3	3	3	3	3	3	3	3	3
13. Response Time	Milliseconds	3-7	3-7	3-7	3-7	3-7	3-7	3-7	3-7	3-7	3-7	3-7
14. Life	Operations	--	--	--	--	--	--	--	--	--	--	--
15. Remarks		2 3	2 5	2 4 5	1 2 6	1 2 4 6	1 2 7 8	4 9 11 12	9 11 12	4 10 11 12	10 11 12	5

Remarks: [1]Inertias shown for uncoupled and coupled shafts [2]Max. recommended speed. 7500 rpm [3]Brakes until signal applied when energized [7]Declutches when energized [8]Output brakes [9]Single end [10]Double end [11]Engages when energized [12]Inertias are output when de-energized [13]Brakes when de-energized

Summary of Physical and Performance Characteristics of Clutches and Brakes (Cont.)

AUTOTRONICS, INC. (Cont.)

1.	C-4	C-6	C-8	C-10	CF-4	CF-6	CF-8	CF-10	MBB-4	MBB-6	MBB-8	MBB-10	MCC-4	MCC-6	MCC-8	MCC-10
2.	Clutch	Clutch	Clutch	Clutch	Clutch	Clutch	Clutch	Clutch	Cl. Br.	Cl. Br.	Cl. Br.	Cl. Br.	Dup. Cl.	Dup. Cl.	Dup. Cl.	Dup. Cl.
3.	.594	.827	1.090	1.370	.594	.827	1.090	1.370	.594	.827	1.090	1.370	.594	.827	1.090	1.370
4.	.882	1.240	1.485	1.620	.965	1.350	1.628	1.740	1.436	2.050	2.516	2.735	1.581	2.271	2.753	2.986
5.	3.5	14.0	32.0	56.0	2.0	8.0	16.0	30.0	3.5	14.0	32.0	56.0	3.5	14.0	32.0	56.0
6.	--	--	--	--	--	--	--	--	3.5	14.0	32.0	56.0	--	--	--	--
7.	.05	.10	.10	.10	.05	.20	.50	.50	.05	.10	.10	.10	.05	.10	.10	.10
8.	.05	.25	.50	.50	--	--	--	--	.15	.25	.50	.50	.05	.25	.50	.50
9.	.47	3.7	13.0	19.3	.45	2.8	8.5	15.1	.45	2.8	8.5	15.2	.45	3.7	13.0	19.3
10.	--	--	--	--	--	--	--	--	--	--	--	--	.45	3.7	13.0	19.3
11.	.40	1.6	5.4	13.5	.36-d	1.8-d	5.4-d	14.1-d	.51	2.6	8.7	23.8	.61	2.6	8.7	23.7
12.	2.5	3.5	4.0	4.5	2.5	3.5	4.0	4.5	2.5/coil	3.5/coil	4.0/coil	4.5/coil	2.5	3.5	4.0	4.5
13.	3.4	10.0	24.0	32.0	6.5	8.0	16.0	30.0	3.4	9.5	24.0	32.0	3.4	10.0	24.0	32.0
14.	Over 10^8 cycles at 60 cps. (through MCC-10)															
15.					Shafts coupled when deenergized; decoupled when energized.				Input, output free-running when deenergized. Energize coil "X" to couple input and output. Energize coil "Y" for free-running input, output braked.				Deenergized, 2 inputs and output running free. Energizing either of 2 coils engages its input to output shaft.			

DYNAMIC INSTRUMENT CORP. (Cont.)

KEARFOTT DIV., GENERAL PRECISION INC.

1.	D-MCSC -5	D-MCSC -8	D-MCSC -11	D-MCSC -13	D-MCSC -18	D-SC-5	D-SC-8	D-SC-11	D-SC-13	D-SC-18	R 5750 -001	R 5750 -002	R 5760 -001	R 5770 -001
2.	Dup.Cl.	Dup.Cl.	Dup. Cl.	Dup. Cl.	Dup. Cl.	Clutch	Clutch	Clutch	Clutch	Clutch	Clutch	Clutch	Br. Cl.	Brake
3.	.594	.827	1.090	1.370	1.750	.594	.827	1.090	1.370	1.750	1.062	1.062	1.062	1.062
4.	.965	1.350	1.628	1.740	2.042	.965	1.350	1.620	1.740	2.042	1-45/64	1-45/64	1-45/64	1-45/64
5	4/3	16/12	32/24	60/45	120/90	3	12	24	45	90	6-e	6-d	4-e	--
6.	--	--	--	--	--	--	--	--	--	--	--	--	6-d	16-e
7.	.25	.15	.20	.25	.35	.08	.15	.20	.25	.35	--	--	--	--
8.	.10	.10	.10	.20	.20	.05/.05	.10/.08	.10/.08	.20/.15	.20/.15	--	--	--	--
9.	.50	2.2	7.1	19.0	62.5	.10	.62	2.1	6.5	15.7	.56-d	.56-d	.56-d	.34
10.	.10	.62	2.1	6.5	15.9	--	--	--	--	--	.82-e	.82-e	.82-e	--
11.	.21	1.04	3.5	10.6	36.3	.59	3.3	10.5	19.2	53.3	--	--	--	--
12.	2.5	3	3.5	4	5	2.5	3	3.5	4	5	3	3	3	3
13.	6	11	30	36	42	6.0	11.0	30.0	36.0	42.0	--	--	--	--
14.	--	--	--	--	--	--	--	--	--	--	3 million cycles at 500 rpm			
15.	Shaft couples either of two outputs, depending upon energization. Torque values are energized and deenergized respectively.					← Opens when energized. Drag torque values are for 2 separate shafts when energized.								

FAE INSTRUMENT CORP. (Cont.)

GENERAL-ELECTRO MECHANICAL CORP.

STEARNS ELEC. CORP.

1.	F-29	F-21	F-22	F-25	F-26	FB-25-1	FFC-35-1	FFC-160-1	SFFB-4-1	1.2SM	1.8SM	2.2SM	SC No. 2
2.	Brake	Cl. Br.	Cl. Br.	Cl. Br.	Cl. Br.	Brake	Clutch	Clutch	Clutch	Clutch	Clutch	Clutch	Brake
3.	1.75	1.75	1.75	1.75	1.75	.900	1.093	1-13/16 sq.	.595	7/8 sq.	1-1/8 sq.	1-13/16 sq.	1.375
4.	2-1/8	2-1/8	2-1/8	2-1/8	2-1/8	.530	7/8	1-3/8	.850	7/8	1	1-3/8	2.031
5.	--	80	38	80	40	--	35	160	6	20	32	128	--
6.	20	12	12	15	15	25	--	--	--	--	--	--	25
7.	.03	.03	.03	.03	.03	.5	--	--	low	--	--	--	--
8.	--	--	.08	.08	.08	--	.5	3	low	--	--	--	--
9.	9.1-e	25.6-e	25.6-e	25.6-e	25.6-e	--	81	406	--	--	--	--	--
10.	--	--	--	--	--	--	--	--	--	--	--	--	--
11.	--	--	--	--	--	14.4	27	230	1.26	--	--	--	--
12.	3	3	3	3	3	3	8	9	2.5	2.85	4.2	4.6	4.9
13.	3-7	3-7	3-7	3-7	3-7	10	10	16	4	16/8	18/8	27/10	17/67
14.	--	--	--	--	--	--	--	--	--	--	--	--	--
15.	[14] [4] [5] [12] Crown tooth for disengaged and engaged condition		[6] [12]	[4] [6] [12] Brakes when energized		[6] [12] Clutches Brakes	.024 hp@ 1000 rpm	.035 hp@ 1000 rpm	.159 hp@ 1000 rpm	.006 hp@ 1000 rpm	Other mounting available. Response time indicates times of engagement and disengagement. 5000 max.rpm.			

Summary of Physical and Performance Characteristics of Clutches and Brakes (Cont.)

	Units	STEARNS (Cont.)		REEVES INSTRUMENT CORP.							
1. Model		MP No. 3	SD No. 2	SR3066-1	SR3066-2	SR3066-3	SR3066-4	SR3066-5	SR6166-2	SR6166-3	SR6166-5
2. Type of Device	--	Cl. Br.	Clutch	Clutch	Cl. Br.	Cl. Br.	Clutch	Cl. Br.	Dup. Cl.	Dup. Cl.	Dup. Cl.
3. Diameter	Inches	1.750	1.343	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
4. Length	Inches	3.938	1.063	2.062	2.062	2.062	2.062	2.062	3.412	3.412	3.412
5. Clutch Torque	Ounce Inches	100	50	80	80	80	16	16	60/10	60	10
6. Brake Torque	Ounce Inches	8	--	--	3	30	--	3	--	--	--
7. No Load Torque (unenergized)	Ounce Inches	--	--	--	--	--	--	--	--	--	--
8. No Load Torque (energized)	Ounce Inches	--	--	--	--	--	--	--	--	--	--
9. Inertia (Input A)	Gm-Cm²	--	--	5.5	5.5	5.5	5.5	5.5	24	24	24
10. Inertia (Input B)	Gm-Cm²	--	--	--	--	--	--	--	--	--	--
11. Inertia (Output)	Gm-Cm²	--	--	7.7	8.2	7.3	7.7	8.2	27	27	27
12. Power Input	Watts	4.2	5.0	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
13. Response Time	Milliseconds	83/17	33/12.5	10/3	10/3	22/3	10/3	10/3	10/3	22/3	10/3
14. Life	Operations	--	--	--	--	--	--	--	--	--	--
15. Remarks		Response times indicate engagement and disengagement		Crown-tooth cl.	Crown tooth cl. fric. br.	Crown tooth cl. crown tooth br.	Fric. cl.	Fric. cl. fric. br.	Crown tooth norm. eng'd other fric. cr. tooth provides more torque	Crown tooth	Friction
						Crown tooth engagement speed, 500 rpm maximum.				Shaft couples to either of 2 end gears.	

	Units	REEVES (Cont.)		ORBIT INSTRUMENT CORP.					
1. Model	--	SR6166-6	SR5066-1	SR5066-4	OR500-G	OR800-G	OR1100-G	OR500-E	OR800-E	OR1100-E
2. Type of Device	--	Dup. Cl.	Clutch	Clutch	Cl. Br.	Cl. Br.	Cl. Br.	Clutch	Clutch	Clutch
3. Diameter	Inches	1.75	1.00	1.00	.594	.827	1.090	.594	.827	1.090
4. Length	Inches	3.412	1.313	1.313	.897	1.256	1.511	.897	1.256	1.511
5. Clutch Torque	Ounce Inches	10/60	25	3	2.5-d	10.0-d	20.0-d	2.5	10	20
6. Brake Torque	Ounce Inches	--	--	--	2.5-e	10.0-e	20.0-e	--	--	--
7. No Load Torque (unenergized)	Ounce Inches	--	--	--	.05	.1	.1	--	--	--
8. No Load Torque (energized)	Ounce Inches	--	--	--	.15	.2	.25	--	--	--
9. Inertia (Input A)	Gm-Cm²	24	.59	.59	.47	3.1	10.2	.47	3.1	10.2
10. Inertia (Input B)	Gm-Cm²	--	--	--	--	--	--	--	--	--
11. Inertia (Output)	Gm-Cm²	27	.60	.60	.45	1.8	5.9	.45	1.8	5.9
12. Power Input	Watts	3.4	1.9	1.9	2.5	3.5	4.0	2.5	3.5	4.0
13. Response Time	Milliseconds	22/3	7/3	7/3	5.6	8	28	5.6	10	28
14. Life	Operations	--	--	--	--	--	--	--	--	--
15. Remarks		Fric. norm. eng'd, other Cr. tooth provides more torque. see prev. col.	Crown tooth	Friction	Deenergized, input and output coupled. Energized, input free, output braked to housing.			Shafts engaged when deenergized; free running when energized.		
				Clutches when energized						

	Units	ORBIT INSTRUMENT CORP. (Cont.)					
1. Model		OR500-A	OR800-A	OR1100-A	OR500-D	OR800-D	OR1100-D
2. Type of Device	--	Clutch	Clutch	Clutch	Dup. Cl.	Dup. Cl.	Dup. Cl.
3. Diameter	Inches	.594	.827	1.090	.594	.827	1.090
4. Length	Inches	.897	1.256	1.511	.975	1.352	1.673
5. Clutch Torque	Ounce Inches	5	20	40	2.5	10.0	20.0
6. Brake Torque	Ounce Inches	--	--	--	--	--	--
7. No Load Torque (unenergized)	Ounce Inches	.05	.10	.10	.15	.2	.25
8. No Load Torque (energized)	Ounce Inches	.15	.20	.25	.15	.2	.25
9. Inertia (Input A)	Gm-Cm²	.52	4.1	14.1	.47	3.0	4.5
10. Inertia (Input B)	Gm-Cm²	--	--	--	.52	4.2	14.7
11. Inertia (Output)	Gm-Cm²	.45	1.8	5.9	.39	2.0	5.6
12. Power Input	Watts	2.5	3.5	4.0	2.5	3.5	4.0
13. Response Time	Milliseconds	4.2	8	25	5.6	8	28
14. Life	Operations	--	--	--	--	--	--
15. Remarks		Shafts couple when energized; otherwise free.			Input "N" clutches output shaft when de-energized otherwise input "M".		

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STERLING PRECISION CORP. and PIC DESIGN CORP. provide from stock a broad line of magnetic clutches which are described in their standard catalogs along with other servo and breadboarding equipment.

GLOBE INDUSTRIES

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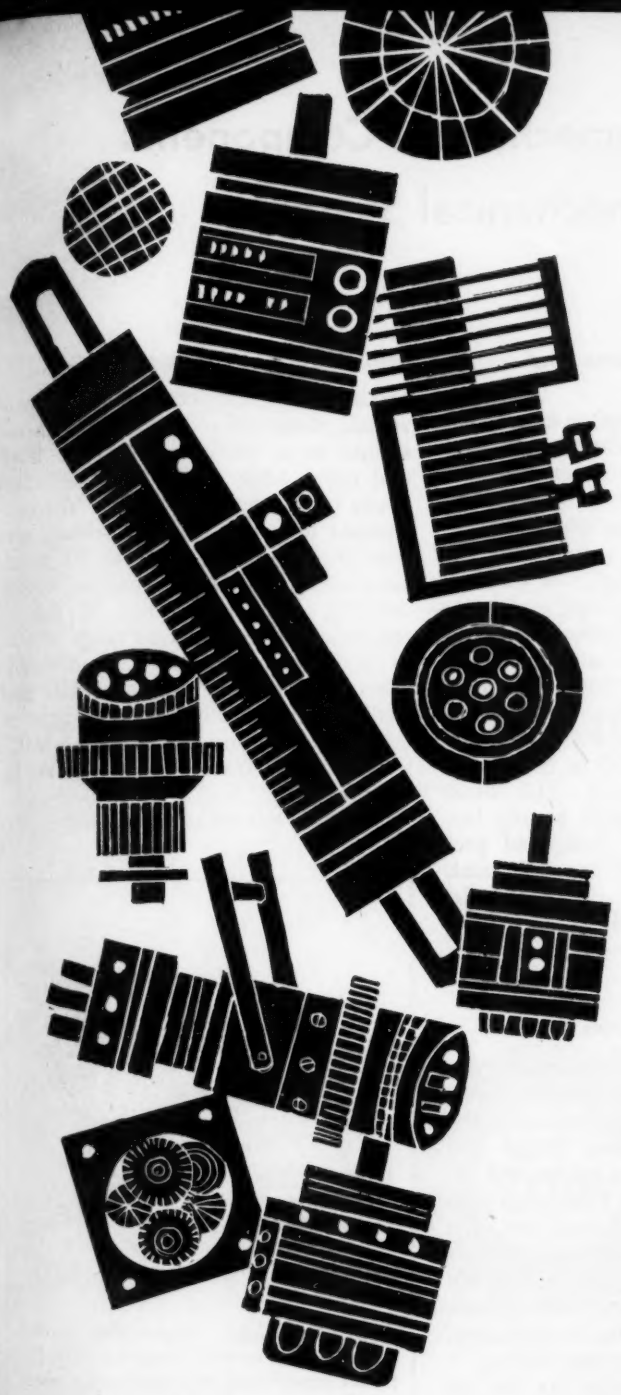
MAGTROL, INC. and DYNEX CO. also produce lines of magnetic clutches. Information supplied by these Companies did not contain data in the form required for inclusion in these charts.



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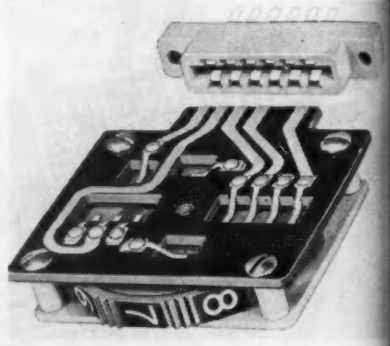
Circle No. 156 on Inquiry Card.



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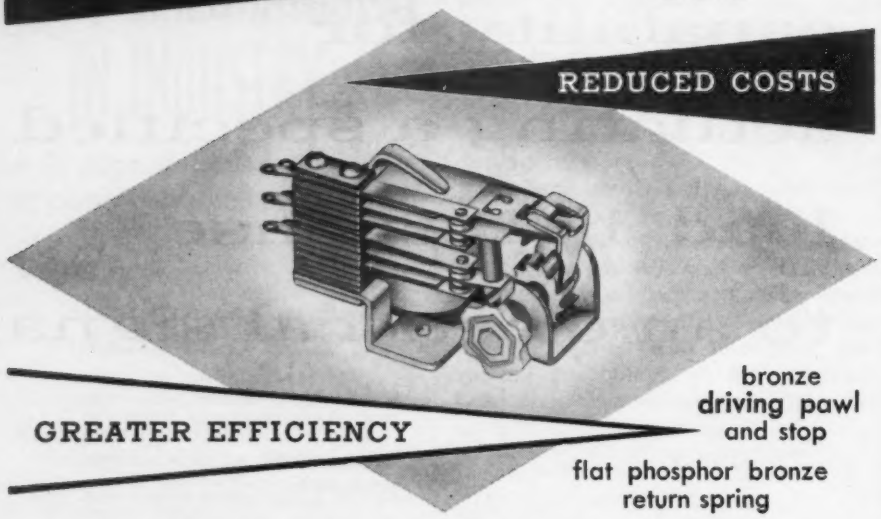

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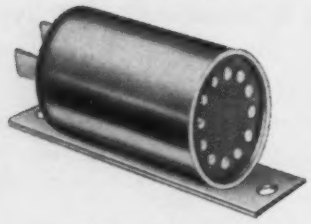
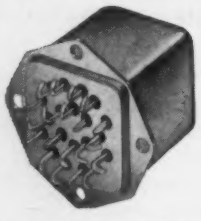
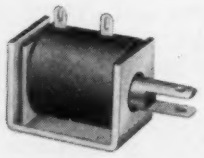


Rotomite
Continuous Duty Stepper



Series 2505 6 P.D.T.
Hermetically Sealed Relay



No. 24 A.C.
Midget Solenoid

GUARDIAN ELECTRIC
MANUFACTURING COMPANY
1641-C W. WALNUT STREET, CHICAGO 12, ILLINOIS
CIRCLE NO. 64 ON INQUIRY CARD

ELECTROMECHANICAL COMPONENTS

Miniature Coaxial Switch

A miniaturized coaxial SPDT switch, said to be the smallest on the market, maintains all the electrical and mechanical features of normal coaxial switches. The new switch for 50 ohm cable is designed so that it can be directly inserted into a miniaturized circuit without adapters. Positive toggle action assures proper switching action and panel mounting provides easy installation. Mating connectors are available for application at, above, or below 400 mc. VSWR is less than 1.2 to 2 kmc and insertion loss is 0.5 db at 2.0 kmc. Voltage rating is at 1500 volts maximum (60 cps) and crosstalk is better than 60 db to 2.0 kmc. Operative life is at a minimum of 50,000 cycles. The switch weighs only 1¼ ounces. Microdot Inc., So. Pasadena, Cal.

Circle No. 204 on Inquiry Card.

Low Cost Pressure Transducer

Low cost gage and absolute pressure transducer, designed for "off-the-shelf" delivery has pressure ranges of 0-150 to 0-2500 psig with resistances of 1K, 2K, 5K and 10K, ±5%. Weighing only 10 ounces, it is built for operation over an ambient temperature range of −40°F to +275°F. Overall accuracies combining the effects of linearity, hysteresis, static friction and resolution are in the order of 2.5% or better. Continuous power rating is 1 watt at 68°F and 0.75 watt at 165°F. Conforms to environmental requirements of MIL-E-5272B. Edcliff Instr., Monrovia, Cal.

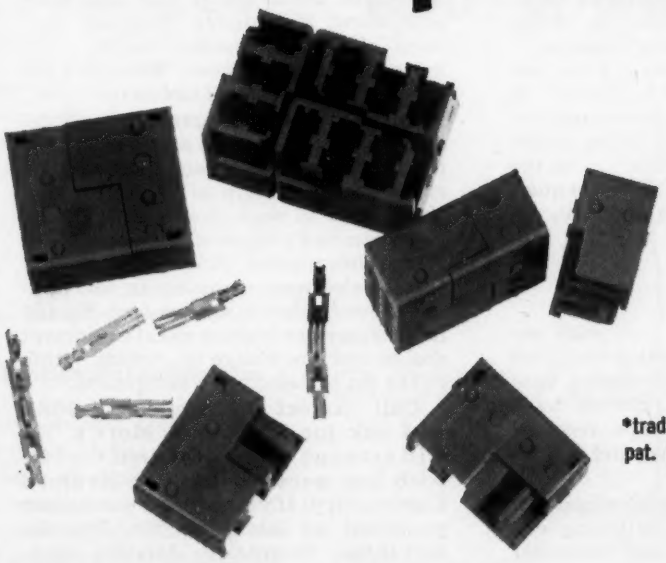
Circle No. 198 on Inquiry Card.

Pneumatic Control

A variable speed drive called Servotran fitted with a diaphragm for vacuum or pressure control is ideal for pneumatic control because only a couple of inch ounces pressure on the control shaft is required to change speed. Speed control over the range from full speed forward to full speed reverse is achieved with a pressure range of approximately 0 to 10 in. of water. The drive can also be furnished with a smaller diaphragm for much higher working pressures. Horsepower range varies from 1/1000 to 1/100 hp all the way up to 1/10 hp. A husky ¾ hp model is offered for smaller speed ranges. Humphrey Products Division, San Diego, California.

Circle No. 218 on Inquiry Card.

MEET morpho*



*trademark pat. pend.

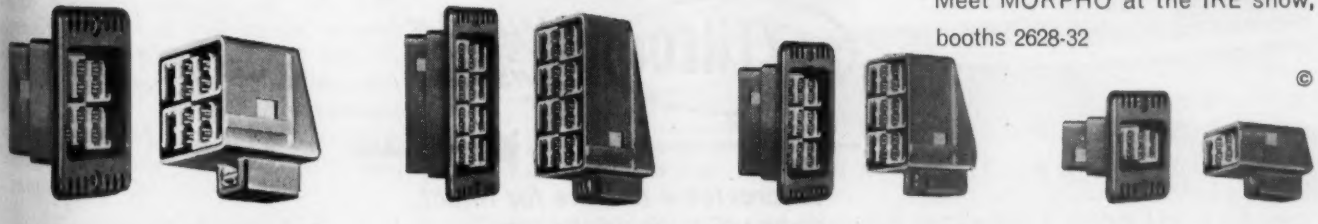
THE SYMBOL OF A MOST UNUSUAL NEW DEVELOPMENT BY CANNON

Meet MORPHO—he represents the most versatile plug you ever saw! MORPHO is Cannon Electric Company's unusual *new* development for meeting many industrial and military requirements *inexpensively*. Check these features! ▪ Crimp-type contacts supplied loose for crimping with a simple hand tool, or in belts for crimping with a semi-automatic tool ▪ Easiest installation ever, just snap into insulators, module insulators designed for alternate positioning for maximum adaptability ▪ Hermaphrodite design, contacts and insulators can be used in either plug or receptacle! MORPHO plugs have been tested to severe requirements, are available in different configurations with a wide range of contact layouts. Write for Catalog MH-1 *today* and meet MORPHO for yourself...another reason why you should always consult the *first* name in plugs — why you should *consult Cannon for all your plug requirements.*

CANNON PLUGS

Meet MORPHO at the IRE show, booths 2628-32

CANNON ELECTRIC CO., 3208 Humboldt St., Los Angeles 31, Calif.



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CIRCLE NO. 65 ON INQUIRY CARD

PROJECT CR 4-8884

It takes less than a minute. But it could be the biggest project of your life when you dial CRestview 4-8884. Your *future* is literally at your fingertips, and it's an opportunity-filled future with the Bedford Laboratory of Raytheon Company in Bedford, Massachusetts. In this key laboratory of Raytheon Company's Missile Systems Division a man can literally "pick his spot". Ability is quickly recognized . . . achievement rewarded. And, working and living conditions are the finest available . . . in the heart of New England. If YOU can qualify for one of the following positions, act NOW!

Immediate Openings for:

Data Handling Engineers . . . with experience in high speed, analog-to-digital conversion techniques, logic design, converter and buffer design. Should have thorough knowledge of tape recorder techniques and digital, servo, and digital-computer design.

Circuit Design Engineers...with experience in design of high-speed switching circuits, pulse techniques, and computer logic. Should be experienced in one or more of the following areas: navigation, guidance, control circuits, CCM, FM, PCM, PDM, and fusing circuitry.

Packaging Engineers . . . with a knowledge of packaging and production techniques in sheet metal and electronic equipment. Will design electronic portions of guided missiles, radars, computers, test equipment. Should have thorough knowledge of circuitry.

Electromechanical Designers . . . will design electromechanical equipment and electronic portions of guided missiles, including coordination of effort through the shop. Will work closely with Design Engineers in developing electronic packaging philosophies. Knowledge of electronics, electronic components, and ability to read schematics required. Should have experience in sheet metal equipment design and knowledge of current "state of the art" in electronic equipment.

Call collect CRestview 4-8884 and ask for Mr. Jerry Morris. He will arrange an appointment for you with key personnel at the Bedford Laboratory. If you prefer, send your postcard or letter to Mr. Morris, Raytheon Company, Missile Systems Division, Bedford, Mass.

RAYTHEON MISSILE SYSTEMS DIVISION

...creates a climate for talent.

CIRCLE NO. 66 ON INQUIRY CARD

ELCTROMECHANICAL COMPONENTS

Shaft Position Encoder

Accurate to one part in 1,000, per single turn of input shaft, 6" diameter analog to digital converter provides three decimal digits in binary coded decimal for each revolution of input shaft. Other models of this family provide greater resolution through multiple shaft rotation and internal cascading of down geared code discs in ratio of one shaft revolution for each 1,000 counts. These include a 10,000 count 10-turn encoder, and a 100,000 count 100-turn encoder, and a 1,000,000 count 1000-turn encoder. All units feature internal self-selecting V-brush logic for ambiguous readings, relatively long life and a high degree of reliability. Applicable MIL specs are met. Norden Div., United Aircraft Corporation, Stamford, Conn.

Circle No. 225 on Inquiry Card.

Free Gyro

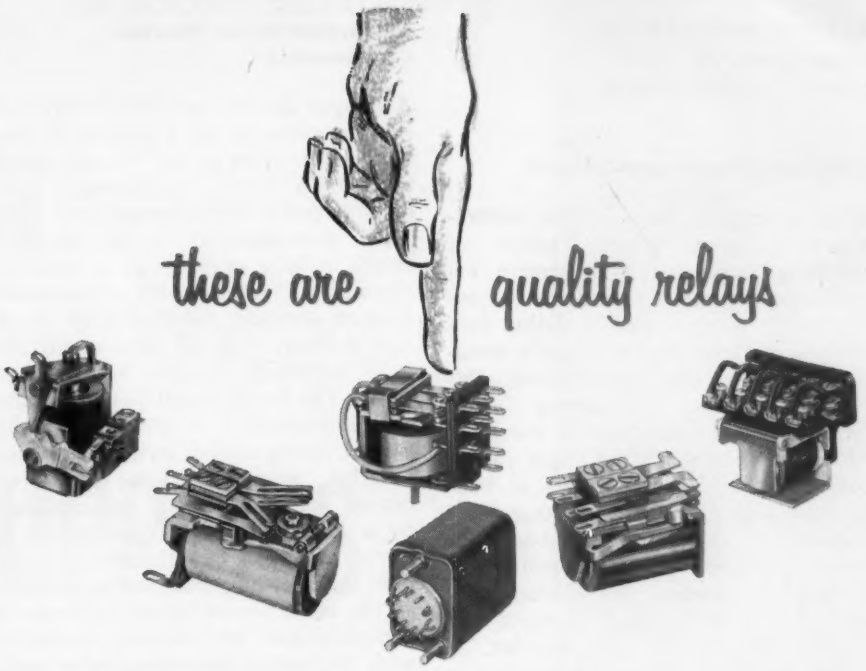
Highly reliable, two-degree-of-freedom gyro uses ac synchro transmitters located at each gimbal axis to provide extremely accurate angular displacement information. A. C. torquers mounted at each gimbal axis permit command positioning or slaving of spin axis to desired reference position, and each torquer is capable of producing a precession rate of 360°/minute with 12.5 watts/phase power input. The squirrel cage, induction-type motor of this unit is designed for minimum size, fast runup ability, and low power consumption at operating speed. This free gyro is designed to operate without diminished performance in extreme shock, temperature, and vibrational environments. Kearfott Company Inc., Clifton, New Jersey.

Circle No. 184 on Inquiry Card.

1/2" Linear Motion Potentiometer

A new ½" linear motion potentiometer with a temperature range from —65° to 275° has been designed specifically for internal installation in hydraulic actuators. Capable of withstanding vibration to 35 g, critical elements of the pot are isolated and oil sealed within a high-strength alloy case. Specifications include: ranges ⅛" to 12", linearity 0.5% of full range, overall length 1.875" plus travel and MIL-E-5272-A for sand, dust, humidity, etc. Mountings or electrical connections can be modified for particular requirements. Servonic Instruments, Inc., Costa Mesa, Cal.

Circle No. 128 on Inquiry Card.



We put a lot of quality in our relays. We start with skilled design and quality materials. Then we add precision workmanship, modern production techniques and rigid inspection. The resulting relays are top quality units, outstanding in performance, dependable in operation. This extra quality you get from Comar costs no more, but it does pay big dividends. Next time you need quality relays—

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3349 ADDISON STREET • CHICAGO 18, ILLINOIS

RELAYS • SOLENOIDS • COILS • SWITCHES • HERMETIC SEALING

CIRCLE NO. 67 ON INQUIRY CARD

ELECTROMECHANICAL COMPONENTS

Electrohydraulic Servo Valve

A unity-coupled shear orifice, electrohydraulic servo valve, capable of optimum performance in severe environments, consists of only two moving parts: a spool and a sliding fork integral with a torque motor's armature. Of titanium construction, this valve has large, full-opening "shear seal" orifices which virtually eliminate silting problems, while high shear forces easily clear the valve of contaminants. Essentially a two-stage four-way control valve; the first stage consists of an electrical torque motor and hydraulic amplifier, the second consists of a precisely matched spool and sleeve arrangement. The manner in which these two stages are coupled is unique. Hydromechanical unity feedback relates spool position to torque motor armature position and also nulls out the affects of orifice variations produced by fluctuations in supply pressure and temperature. Hydraulic centering of the pilot position is accomplished without the spring hysteresis and null shift commonly encountered in valves using the force feedback principle. Final null adjustments are made electrically by a balancing control at the amplifier output stage. Kearfott Company, Inc., Clifton, New Jersey.

Circle No. 169 on Inquiry Card

Magnetic Readout Digital Encoder

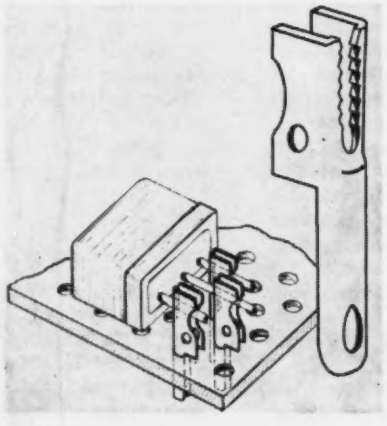
A new shaft-position digital encoder with 13 bit binary output employs a unique, noncontacting magnetic readout. Only bearings and gears affect life permitting operation in any environment, at speeds up to 10,000 rpm. and with any number of readouts without effect. The readout method employs subminiature, ferrite toroids mounted above, but not touching, code tracks of magnetized spots on barium ferrite disks. Two disks are used, a 2^7 disk connected to a 2^6 disk through a 64:1 gear reduction. As a toroid readout head enters the magnetic field of the code spot, it saturates and its impedance drops. When the head is interrogated by a constant current pulse train, an output is obtained only when the head is unsaturated, i.e. outside the influence of a code spot. Because of the singular geometry of the field and toroid, no emf or spurious pulses are generated when the shaft is rotating, and there is no shaft load. ASCOP, Inc., Princeton, N. J.

Circle No. 135 on Inquiry Card

Millimeter-Wave Ferrite Components

A unique line of millimeter-wave ferrite components is available to the engineer working in the V-Band, covering 60-75 KMC. Lightweight and miniaturized each component will withstand pressurization to 30 psi. The ferrite isolator operates as a non-reciprocal 45° rotator with a permanent magnet suppling the bias field. Isolation is larger than 17 db over at least a 3% band with insertion loss less than .6 db. The ferrite on-off switch or variable attenuator is a low-power lightweight fast-operating switch with high isolation when off, low loss when turned on. Switching is accomplished by a coil in 1 to 2 microseconds. A ferrite circulator is a lightweight four-port device using polarization rotation as the basic non-reciprocal element. A non-reciprocal 45° rotator combined with dual-mode transducers plus input and output taper sections make up the complete circulator. Peak power unpressurized is 10 KW, average power 2 watts. A ferrite high-power reciprocal switch operates by means of a ferrite rotator and a dual-mode transducer so that an input signal may be switched to either of two arms. Switching time is 1 to 2 microseconds. Peak power is at least 10 KW, unpressurized. T.R.G., Inc., Somerville, Mass.

Circle No. 151 on Inquiry Card



Terminal For Miniature Circuitry

A new push-in terminal for 1/16" round holes is available. The terminal holds firmly when pushed in by hand and need not be staked. As many as six leads may be connected to it in the three possible directions. Even though small in size it is ruggedly built of heat treated beryllium copper with a fused tin finish for good soldering. Vector Electronic Company, Glendale, California.

Circle No. 186 on Inquiry Card

Modular Temperature Scanner

A new modular temperature scanner precisely monitors up to 50 modular assemblies of temperature-sensitive elements (thermocouple or thermistor). The modules consist of relays and potentiometers, mounted on a plug-in base. Each module is a complete unit identical in design and configuration to every other module. New points may be added by plugging in a module and connecting the sensor leads. If more than 50 points are required, additional scanners can be used. No critical circuits are interrupted if a module is removed. Each module may have a different temperature limit. The scanning indicator (meter relay) reads each point successively and sounds an alarm and lights the numbered module of any point exceeding the limit. The scanner continues to scan all points below the trip level, regardless of how many have exceeded the alarm point. Tipptronic, Inc. Chagrin Falls, Ohio.

Circle No. 139 on Inquiry Card

Round Chart Recorder-Controller

A new round chart recorder with accuracies of ±¼% contains components that are interchangeable with those of existing strip-chart models. The null-balance potentiometer-type recorder has a minimum accurate scale span of 1 millivolt dc. Response times available are 4, 10, and 24 seconds full scale. A zener diode, which eliminates use of a dry cell or standard cell power supply, gives a constant voltage reference accurate to ±0.05%. The control portion of the recorder features individually adjustable, trip switch cams. General Electric, Schenectady, N.Y.

Circle No. 221 on Inquiry Card.

Relay Actuator

Based on a design that senses the magnetic field created by the current in a wire placed through a hole in a toroid, this unit gives relay actuation as low as 4.5 amps, depending on the characteristics of the relay used. The actuator has no moving parts, eliminates mechanical timers normally used in such applications as welding, and has no upper current limitations; it can be used for alternate and direct current systems. Extremely easy to mount, the current carrying wire is slipped through the toroid, and the relay to be actuated is placed in series with the toroid unit. L and B Electronics, 2424 Sixth Street, Berkeley, California.

Circle No. 245 on Inquiry Card.

IRE BOOTHS 2213 & 2215

REGATRAN®
SEMICONDUCTOR
POWER SUPPLIES...

Here's reliability . . . Since their introduction, over 18 30 months ago, not one Regatran has lost a series transistor due to short circuits or overloading.

- transistorized
- short circuit proof
- super-regulated
- overload protected
- low output impedance
- lowest ripple
- High-speed regulation
- null balance control
- sensing terminations
- front panel calibration
- any grounding arrangement
- small size, light weight

MODEL T036-5M

NOW... higher current REGATRANS

WIDE RANGE MODELS

MODEL NUMBER	D-C OUTPUT	
	VOLTS	AMPS
T060-15	0-60	0-15
T036-30	0-35	0-30
T032-30	0-32	0-30
T014-30	0-14	0-30
T07-30	0-7	0-30

Brief Specifications (all models)

REGULATION, LINE OR LOAD: 0.03% or 0.01 V (0.01% or 0.003 V available).

RIPPLE: Less than 1 millivolt rms.

CIRCUIT PROTECTION: (1) electronic circuit breaker plus (2) electromagnetic circuit breaker plus (3) input line fused.

NARROW RANGE MODELS ALSO AVAILABLE

REQUEST BULLETIN 721A (Revised) FOR COMPLETE SPECIFICATIONS

ELECTRONIC MEASUREMENTS
COMPANY OF RED BANK
RED BANK • NEW JERSEY

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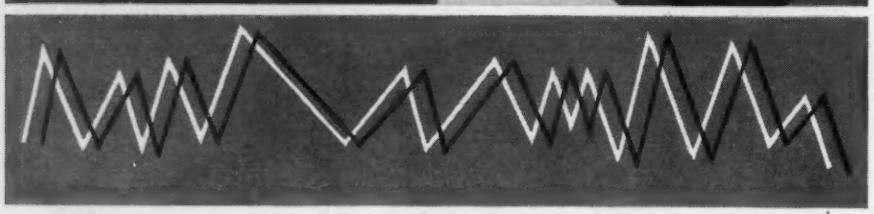
CIRCLE NO 69 ON INQUIRY CARD

ELECTRONIC ENGINEERS

COUNTERMEASURE-PROOF AIRBORNE COMMUNICATIONS

...one of many exciting programs with long-term importance attracting engineers to General Electric's Light Military Electronics Department



Light Military engineers are developing an airborne communications system with ability to maintain efficient operation in the face of intense and sustained electromagnetic interference. Embodying in its design a number of new concepts, this low-weight system possesses long-range capability as well as extreme reliability.

There are Immediate Openings on this Advanced Program

ECM-Proofed Communications afford unusual opportunities for communications systems design engineers to make measurable contributions in the design of the airborne or space terminal. Within this work program there is opportunity to formulate new techniques in RF power generation, modulation and coding, including error correction. Additionally there are challenging openings for engineers with backgrounds in transmitter/receiver design, logic design, RF and digital transistor circuit design, microwave and cavity design.

Other stimulating programs under way at LMED on which a number of professional staff openings are available include Polaris Fire Control and Guidance Computer, ICBM Guidance, Airborne ECM and Airborne Navigation Systems.

Address your inquiry in complete confidence to:
Mr. Ron Bach, Dept. 29-MC

LMED

LIGHT MILITARY ELECTRONICS DEPARTMENT

GENERAL ELECTRIC

FRENCH ROAD, UTICA, NEW YORK

WRITE DIRECT OR CIRCLE 70 ON INQUIRY CARD AND INCLUDE HOME ADDRESS

ELECTROMECHANICAL COMPONENTS

Accelerometer

Potentiometric-type acceleration transducer features a broad bandwidth sensor 0-10 g's flat to 50 cps. The unit offers especially low static friction and high resolution characteristics. The instrument is 1⅛" x 1⅛" x 2¼" and weighs less than 5 ounces. Avionics Corp., Plainview, Long Island, N. Y.

Circle No. 224 on Inquiry Card.

400-Cycle Unrectified Solenoids

A linear-magnetic actuator which operates without rectification from a 400 ac power source may be used singly or stack-mounted for multiple performance. Available in two sizes, the units have externally adjustable stroke length and linear action that may be either push or pull. The smaller model weighs but 1.3 ounces and consumes 13 watts; the larger model weighs 5.1 ounces and uses 40 watts. Both sizes operate continuously at temperatures from −65°F to 450°F. B. H. Hadley Inc., Los Angeles, California.

Circle No. 259 on Inquiry Card.

Size 8 Modular Assembly

A pre-packaged modular assembly of size 8 components consisting of a motor generator, gear train, synchro and potentiometer, are accurately aligned and calibrated with each other, saving valuable time and assuring maximum performance for the user. Motor generator is rated for 26v per phase or with 36v center tap control phase; gear train can be furnished in any ratio up to 6000:1, synchro has 7 minute accuracy and potentiometer is available in any resistance up to 100K. John Oster Mfg. Co., Racine Wisconsin.

Circle No. 199 on Inquiry Card.

Amplifier/Resolver Module

A new amplifier/resolver module only 3" long consists of a size 8 winding compensated resolver and a dual channel buffer amplifier within a size 15 frame. Weighing only 8 ounces, the unit called the Amplisolver, offers unity transformation ratio with zero phase shift over a temperature range from −55°C to +125°C. Trim adjustment can be made in the field to ±2% of unity transformation ratio. A versatile design permits adaptation to computing chain functions. Instrument Division, American Electronics, Inc., Culver City, California.

Circle No. 133 on Inquiry Card

E-W Custom Cooling

Condition: Unusual Configuration

Today's electronic systems invariably require specialized cooling equipment that is compact, lightweight, fits into unusual configurations, and still meets the most difficult environmental conditions (MIL-E-4970*).

Custom air-conditioning is our business at Ellis and Watts. For example, our MIL-AC air conditioning units can be square, oblong, L-shaped, T-shaped, curved, pyramid—virtually any shape your conditions require. They can be designed for integral mounting in electronic consoles or computer racks; or for use as adjacent or remote equipment to air condition entire systems.

MIL-AC units are self-contained, compact, lightweight, readily air-transportable. They can be designed to cool, heat, humidify, dehumidify, filter, and can incorporate air-cooled or water-cooled condensers. Units are manually or automatically controlled. We are staffed with specialists who will analyze your requirements, submit a proposal, complete your installation promptly and to your complete satisfaction.

Write for helpful load calculating Nomograph and other technical data for use in making time-saving preliminary calculations.

*Military specification dealing with the following climatic and environmental conditions: Temperature, humidity, altitude, salt spray, vibration, fungus, sunshine, rain, sand and dust, explosive atmosphere, acceleration and shock

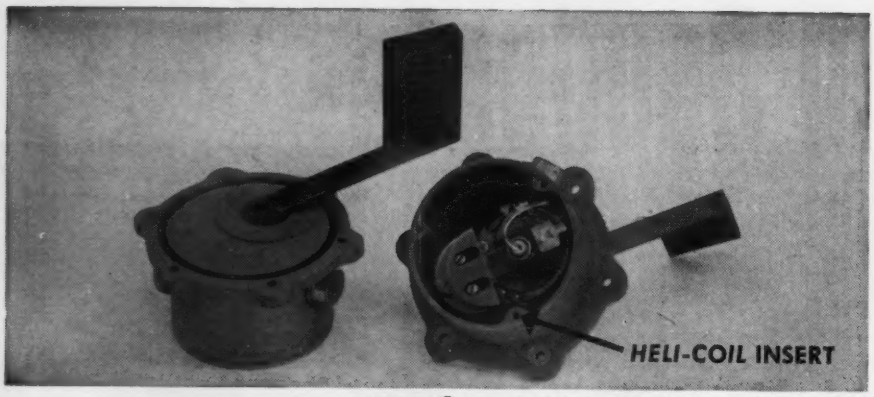
Typical MIL-AC *Unit.* MIL-AC *configurations, features and functions to suit your specific requirements.*

ELLIS AND WATTS PRODUCTS, INC.

P.O. Box 33M, Cincinnati 36, Ohio

Ellis and Watts also design and build custom air conditioners, liquid coolers and heaters, dehumidifiers, wave guide dehumidifiers, laboratory temperature and humidity control units.

CIRCLE NO. 71 ON INQUIRY CARD



Heli-Coil® Screw-Lock Inserts* lock screws against impact and vibration and permanently protect critical tapped holes in this transducer assembly.

Critical Electronic Controls Get Internal-Locking, Protective Threads

with

HELI-COIL

Screw-Lock Inserts

Principle of *Heli-Coil* Screw-LOCK Insert. Locking center coil grips internally, holds screw firmly.

Electronic control devices for aircraft and missiles, like this angle of attack vane transducer made by U. S. SCIENCE CORPORATION, LOS ANGELES, CALIF., have to withstand severe vibration, impact, corrosion and temperature change. They must be made of light materials and still have strong threads — able to hold fasteners tightly and stand frequent assembly and disassembly.

U. S. SCIENCE insures rock-solid screw assemblies by protecting vital tapped holes with one-piece *internal-locking Heli-Coil* Screw-LOCK Inserts. These precision formed, stainless steel wire inserts eliminate thread wear, lock screws securely — without resort to clumsy, external lock nuts and lock wiring.

Simple Installation Procedure

U. S. SCIENCE finds it easy to install *Heli-Coil* Screw-LOCK Inserts. Drilled holes are tapped with a *Heli-Coil* tap and the Inserts wound in with a prewinder inserting tool. Conventional screws are used in assembling the unit.

Heli-Coil Screw-LOCK Inserts

- positively lock fasteners against loosening under impact and vibration
- prevent thread wear, stripping, corrosion, galling and seizing
- eliminate lock nuts, lock wiring, other supplementary locking devices
- permit repeated disassembly and reassembly
- can be used in standard proportion bosses without need for redesign
- save assembly time, space, weight and cost
- meet government specs for locking torque and vibration

*Patented

HELI-COIL CORPORATION
DANBURY, CONNECTICUT

HELI-COIL CORPORATION, 2703 Shelter Rock Lane, Danbury, Connecticut
Send complete design data on *Heli-Coil* Screw-LOCK Inserts

NAME _____ TITLE _____

FIRM _____

ADDRESS _____

CITY _____ ZONE ____ STATE _____

In Canada: Armstrong Beverley Engineering Ltd., 6975 Jeanne Manse St., Montreal 15, Que.

CIRCLE NO. 72 ON INQUIRY CARD

ELECTROMECHANICAL COMPONENTS

Flush-Mounted Pressure Transducer

A flush-mounted pressure transducer with improved high-frequency performance is obtainable in pressure ranges from 0-100 to 5000 psi gage and absolute. Because the pressure sensitive diaphragm is flush-mounted, it can easily measure high-frequency transient phenomena. Provision is made for adjustment of bridge balance, temperature compensation and sensitivity external to the unbonded strain gage sensing element. Consolidated Electrodynamics Corp., Pasadena, Cal.

Circle No. 220 on Inquiry Card.

Servo Transducer

A high-precision, high-torque, electronic transducer converts pressure, liquid level, temperature, mechanical motion, etc., into a shaft position for operating transmitting slidewires, alarm switches, analog to digital encoders, deviation contacts, etc. The sensing element may be a capsular element, or it may be a helical element or a differential pressure unit. The motion transmitted from the sensing element through a linkage positions the core of a differential transformer. The coil is repositioned through a mechanical feedback system to return the electrical system to balance. Remote readout is achieved through a retransmitting slidewire. Readout is any function of the measured variable, as determined by the type of cam used in the rebalancing system. Bristol Company, Waterbury, Conn.

Circle No. 153 on Inquiry Card

Feedback Servoactuator

A new line of electrohydraulic servoactuators employs mechanical feedback. Feedback of piston position to the armature of the input force motor is accomplished by springs together with a precision motion reductive device. Error or difference between the input force and the spring feedback force is amplified by a variable orifice hydraulic amplifier, the output of which positions a sliding spool valve that supplies flow to the servopiston. With this arrangement, the actuator position is proportional to the d-c input current. Piston areas to 3 square inches and strokes to 4 inches are available with open loop gains as high as 120 Sec^{-1}. Moog Servocontrols, Inc., East Aurora, New York.

Circle No. 226 on Inquiry Card.

STANDARD AND SPECIAL PURPOSE POWER SUPPLIES FOR

control systems, transistor powering, computer systems, test equipment, guided missile circuits, aircraft electronics, telemetry circuits, DC filament supplies, magnetic amplifier references, bias sources.

TRANSISTORIZED AC TO DC ELASCO MINISOURCE® POWER SUPPLIES

FIXED AND SEMI-VARIABLE

TRANSISTORIZED
Higher current capabilities in a smaller lighter package . . . greatly improved efficiences and reliability . . . less heat per watt input . . . no filament power losses . . . reduced transformer and rectifier losses . . . no warmup time . . . longer life.

COMPLETE SERVICEABILITY
All components accessible for checking and replacement . . . potting has been eliminated and a printed circuit board incorporated for compact packaging.

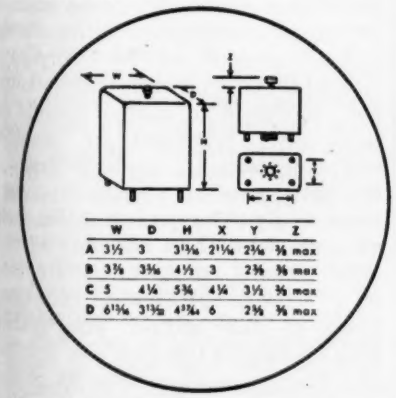
EFFICIENT HEAT TRANSFER
Accomplished by mounting the power transistor on the geometric center of the black anodized aluminum housing, which becomes an efficient black body radiating heat sink . . . Better heat transfer assures more accurate, stable and long-life performance of all components.

FULL PROTECTION
Fusing in the collector of the power transistor protects the supply without affecting regulation.

All standard Minisource® power supplies are furnished with an octal glass to metal header (other terminations available upon request) and packaged in a black anodized aluminum transformer case. There is no extra charge for 400 cycles.

SPECIFICATIONS
VOLTAGE REGULATED — FIXED OR SEMI-VARIABLE * OUTPUT

Input Frequency: 60 cps or 400 cps
Input Voltage: 105-125 VAC
Output Voltage: 4 to 200 VDC
Output Current: 50 to 500 ma
Regulation: Better than 0.5%
Ripple: Less than 0.25%
Polarity: May be used Floating, Positive, or Negative
*Screw driver adjustment on top of semi-variable units.



	W	D	H	X	Y	Z
A	3½	3	3 13/16	2 11/16	2¾	⅜ max
B	3⅜	3⅜	4½	3	2⅜	⅜ max
C	5	4¼	5⅜	4¼	3½	⅜ max
D	6 13/16	3 13/16	4 3/4	6	2⅜	⅜ max

FIXED MINISOURCE

MODEL	VOLTAGE	CURRENT	CASE SIZE
M4.5-50	4.5v.	50 ma	B
M4.5-100	4.5v.	100 ma	B
M4.5-250	4.5v.	250 ma	B
M4.5-500	4.5v.	500 ma	B
M6-50	6v.	50 ma	A
M6-100	6v.	100 ma	A
M6-250	6v.	250 ma	A
M6-500	6v.	500 ma	B
M12-50	12v.	50 ma	A
M12-100	12v.	100 ma	A
M12-250	12v.	250 ma	B
M12-500	12v.	500 ma	B
M22-50	22v.	50 ma	A
M22-100	22v.	100 ma	B
M22-250	22v.	250 ma	B
M22-500	22v.	500 ma	B
M25-50	25v.	50 ma	B
M25-100	25v.	100 ma	B
M25-250	25v.	250 ma	B
M25-500	25v.	500 ma	B
M28-50	28v.	50 ma	B
M28-100	28v.	100 ma	B
M28-250	28v.	250 ma	B
M28-500	28v.	500 ma	B
M30-50	30v.	50 ma	B
M30-100	30v.	100 ma	B
M30-250	30v.	250 ma	B
M30-400	30v.	400 ma	B
M50-50	50v.	50 ma	B
M50-100	50v.	100 ma	B
M50-250	50v.	250 ma	C
M100-100	100v.	100 ma	C
M150-100	150v.	100 ma	C
M200-100	200v.	100 ma	C

SEMI-VARIABLE MINISOURCE

MODEL	VOLTAGE	CURRENT	CASE SIZE
V4-50	3-6v.	50 ma	B
V4-100	3-6v.	100 ma	B
V4-250	3-6v.	250 ma	B
V4-500	3-6v.	500 ma	B
V8-50	5-10v.	50 ma	A
V8-100	5-10v.	100 ma	A
V8-250	5-10v.	250 ma	B
V8-500	5-10v.	500 ma	B
V12-500	10-15v.	500 ma	B
V15-500	10-20v.	500 ma	A
V15-100	10-20v.	100 ma	B
V15-250	10-20v.	250 ma	B
V18-500	15-20v.	500 ma	B
V22-500	20-25v.	500 ma	B
V25-50	20-30v.	50 ma	A
V25-100	20-30v.	100 ma	B
V25-250	20-30v.	250 ma	B
V28-500	25-30v.	500 ma	B
V32-250	30-35v.	250 ma	B
V35-50	30-40v.	50 ma	B
V35-100	30-40v.	100 ma	B
V38-250	35-40v.	250 ma	B
V42-250	40-45v.	250 ma	C
V45-50	40-50v.	50 ma	B
V45-100	40-50v.	100 ma	B
V48-25	45-50v.	25 ma	C
V65-50	60-70v.	50 ma	B
V65-100	60-70v.	100 ma	B
V75-50	70-80v.	50 ma	B
V75-100	70-80v.	100 ma	B

ELASCO can package power supplies in any way the customer may desire (within reason), and to comply with military requirements.

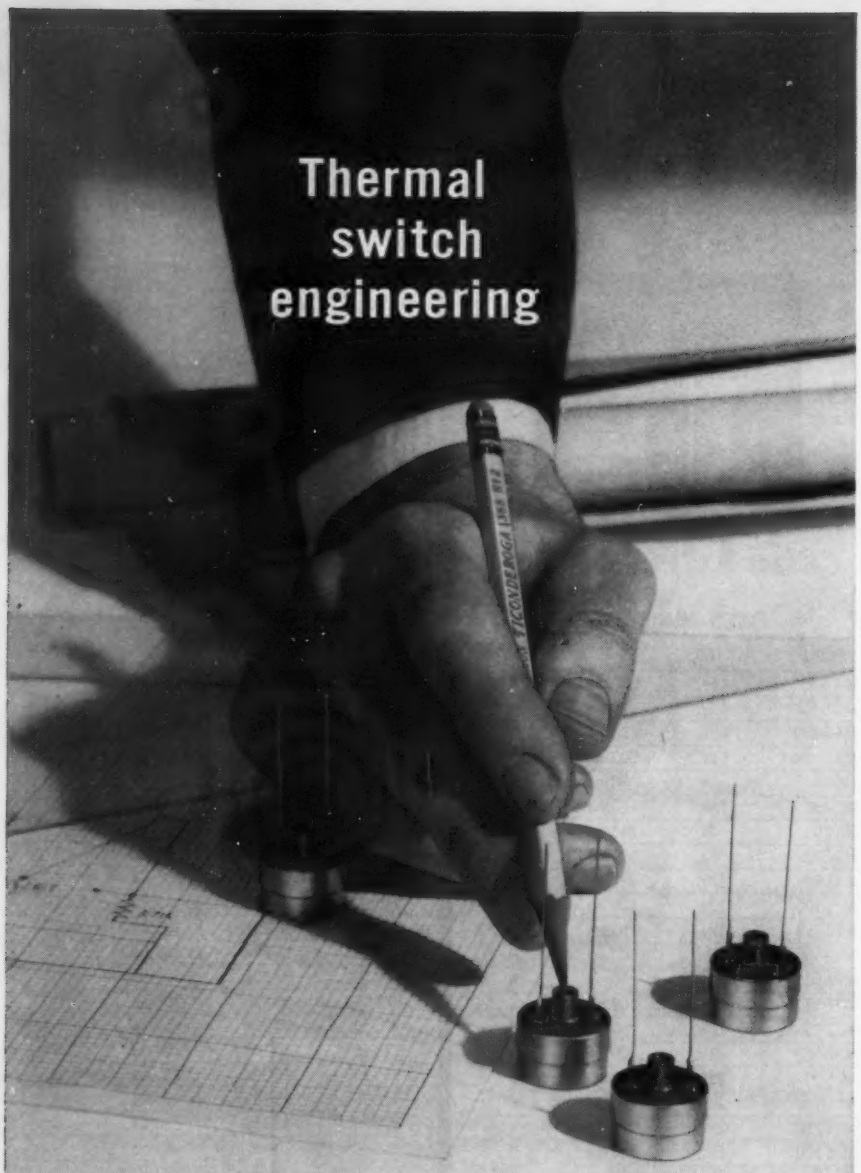
ELASCO inc.

FIVE PRESCOTT STREET, ROXBURY 19, MASSACHUSETTS
Telephone: Highlands 2-1600

IF THE SUPPLY YOU REQUIRE IS NOT LISTED ABOVE, ELASCO WILL BE HAPPY TO BUILD A MINISOURCE® TO YOUR SPECIFICATIONS.

elasco elasco elasco elasco elasco elasco elasco elasco elasco

CIRCLE NO. 73 ON INQUIRY CARD



ANOTHER "CRITICAL" CONTROL SWITCH FROM CPI RESEARCH

If you are concerned with measurement of surface temperatures in aircraft and airborne electronic equipment in confined spaces, this may be a thermal switch you could use. We designed and manufactured it to meet exacting specifications of a prominent aircraft manufacturer.

Chances are your needs may require modifications or even a completely new switch. We have always realized that there are few "critical" control switches that can be all things to all people. That's why we have the research and development engineers who can and do tackle specific problems of thermal control. Can we help you solve yours?

This new hermetically sealed, bi-metal, single or 2-wire switch has calibration range of -20F to 600F; safe momentary overshoot to 800F; available with various type mountings. When inquiring, mention "button" switch.

CPI

CONTROL PRODUCTS, INC.

308 Sussex Street, Harrison, N. J.

CIRCLE NO. 74 ON INQUIRY CARD

ELECTROMECHANICAL COMPONENTS

Pot Permits Gear Coupling

Gear coupling to other elements in system may be obtained with specia shaft flange versions of a precision a- potentiometer. Three mounting hole and an accurate machined slot locat a gear on the pot shaft. Characteristi of the unit include linearities fro ±0.05% output impedances from 4 to 470 ohms, input impedances fro 65,000 to 200,000 ohms, and extreme low phase shift. The ten-turn pot ope ates at 130 volts at a nominal 400-cyc input. Perkin-Elmer Corp., Norwalk Conn.

Circle No. 205 on Inquiry Card.

60 Cycle Motor Generator

Used as a damping tachometer, a ra generator, or an integrator, a 60 cyc motor generator is constructed of co rosion resistant materials and effectiv ly sealed to prevent entrance of du or dirt. The unit features stable outpu voltage over the temperature rang specified, excellent linearity of outpu minimum size and weight, long lif and dependable service. Kearfott Co Inc., Clifton, New Jersey.

Circle No. 219 on Inquiry Card.

High Torque Clutches

A face-tooth electromagnetic clutch claimed to provide the highest torqu in the smallest space of any availabl stationary-field clutch, comes in 5 ra ings from 30 through 725 lb.-ft. torque. The clutches, because of st tionary-field design, virtually elimina the need for maintenance. They ca be buried in a drivebox or transmi sion and forgotten because there a no air gap adjustments to be made, n slip rings and brushes to be cleane adjusted or replaced. By incorporati face-tooth design with the stationar field construction, further specific fe tures and advantages are provided unit assemblies are ready to install o the shaft; ease of adaptability, use three or six drive pins provides a sim ple attachment to driven membe rapid action, engagements are ma in as little as .040 second, disengag ments in .020 second; fine toothi with no flats on top, provides repetiti clutching in small increments of sh rotation and assures that each engag ment is complete; minimum back-la armature spring arrangement assu positive separation of clutch elemen I-T-E Circuit Breaker Co., Phila., P

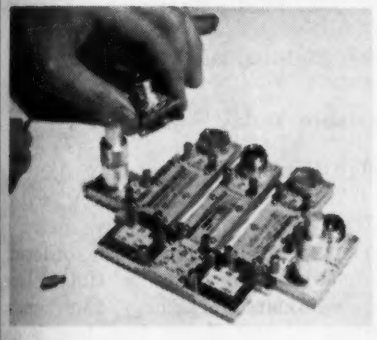
Circle No. 228 on Inquiry Card.

New Electronic Components For Electromechanical Systems

Infrared Measurement

A black body combined with a temperature controller represents an accurately adjustable standard of radiant energy which checks and calibrates other infrared sources and measuring instruments. Designed to emit black body radiation over the temperature range of 500K to 1000K, the stability of its operation is such that the radiation source temperature is maintained within ±1K despite wide changes in ambient temperature, line voltage variations, transients and tube aging. The black body radiator is maintained at the selected temperature by a combination of vacuum-tube amplifier and thyratron circuitry in a power-proportioning temperature controller of high performance. Infrared Standards Lab., Riverside, Cal.

Circle No. 227 on Inquiry Card.



L-Band Modules

Addition of new L-Band units round out a group of strip transmission line modules in this frequency range to include hybrid rings, 3 db and 20 db couplers and a 25 ohm to 50 ohm transformer. These components will mate with the broadband transitions, power dividers, right angle vertical and horizontal bends, 180° bends, straight sections, crystal mounts and terminations now used at both higher and lower frequencies. These modules are standardized "building blocks" that can be quickly connected by thumbscrews to make up a circuit conforming closely in space factor and weight to an integrated strip transmission line circuit. They may be used for breadboarding circuits with substantial savings in time and material. Sanders Associates, Inc., Nashua, N. H.

Circle No. 161 on Inquiry Card

Modular DC Power Supplies

Modular d-c power supplies with outputs ranging from 28 vds, 2 amperes to 500 vdc, 300 milliamperes, are now available with silicon rectifiers. None of these supplies are also available for 50 to 400 cycle operation. The modules are for use individually or with multiple output rack mounting kits. Dressen-Barnes Corp., Pasadena, Cal.

Circle No. 189 on Inquiry Card

Tiny Transistor Amplifier

A tiny "hot-box" transistorized amplifier has a power gain of one quarter of a million and a total volume of three cubic inches. A thermostatically controlled heating element maintains a stable operating temperature for the transistors and minimizes the effect of variations of ambient temperatures. Encapsulation in a special potting compound provides immunity from the effects of humidity, shock and vibration. The direct coupled differential amplifier has excellent stability over the temperature range of 0°F to +130°F. Leach Corp., Compton, Cal.

Circle No. 237 on Inquiry Card.

Space-Saving Transistors

In aircraft and missiles and other computer applications where space is at a premium and weight is a critical factor, new power transistors, called spacesavers are adaptable to a wide variety of mounting requirements. The transistor's low base resistance gives lower input impedance for the same power gain and lower saturation resistance, resulting in lower "switched on" voltage drop. Lower cut off current means better temperature stability in direct coupled circuits and higher "switched off" impedance. Improved frequency response leads to higher audio fidelity, faster switching and improved performance in regulated power supply applications. The spacesaver is available in eight 3-ampere switching types with breakdown voltages of 40, 60, 80 and 100; direct current gain ranges of 30-75 and 60-150 and frequency responses of 20 and 15 kilocycles. Leakage current at 90°C is 10 ma. Clevite Transistor Products, Waltham, Mass.

Circle No. 127 on Inquiry Card.

BASIC BUILDING BLOCKS FROM KEARFOTT

SIZE 11 SYNCHRONOUS MOTOR

Featuring pull out torque efficiency of 50% nominal with 3.4 watts input and 3 watts pull out power, this synchronous motor represents a major achievement in terms of performance for a unit of this extremely small size. Additional advantages made possible by Kearfott's unique design include resistance to environmental extremes, light weight construction and low unit cost. This motor and its variations are available in production quantities.

TYPICAL CHARACTERISTICS R172

Excitation:	Phase 1	Phase 2
Voltage	40V	40V
Frequency	400 CPS	400 CPS
Power	2.3 Watts	2.3 Watts
Current	0.157 Amps	0.157 Amps

Performance:

Synchronous Speed	8000 RPM
Stall Torque	0.2 In. Oz.
Pull Out Torque	0.35 In. Oz.
Pull In Torque	0.15 In. Oz.

Write for complete data.

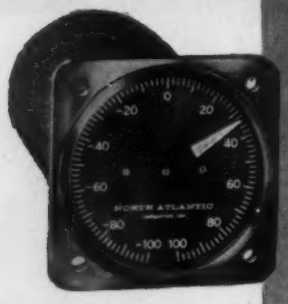
KEARFOTT DIVISION

GENERAL PRECISION INC.

LITTLE FALLS, NEW JERSEY

CIRCLE NO. 75 ON INQUIRY CARD

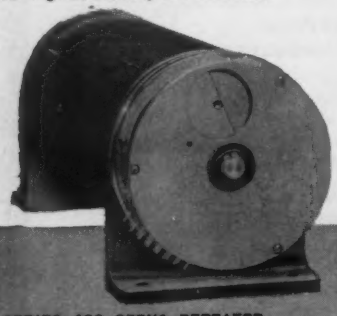
Servo Instrumentation for DATA CONVERSION



SERIES 200 SINGLE POINTER INDICATOR
For applications requiring accuracies and resolutions of less than .2% and high speed of response.

SERIES 200 DUAL POINTER INDICATOR
For high resolution and accuracy application where readability and dynamic response are important.

SERIES 300 DIGITAL DISPLAY INDICATOR
For highest accuracy and resolution.



SERIES 400 SERVO REPEATER
For general purpose repeater and digitizer applications where visual readout is not required.

A complete line of precision, high performance Servo Data Conversion Equipment designed to accommodate any input and output requirement.

Available as

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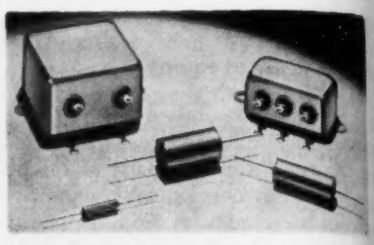
CIRCLE NO. 76 ON INQUIRY CARD



Metallized Mylar Capacitors

New metalized mylar capacitors meet and exceed mil requirements and have many applications. Metallized mylar Dupont polyester film has outstanding advantages which include self-healing characteristics that greatly extend the useful life of the capacitors by eliminating the weak dielectric areas, thereby making full use of the highest volts per-mil rating of the film. Other advantages: extremely small size; dependability; low dielectric absorbtion; high resistance and longer life. The temperature range for operating and storage is −90°C to +125°C; the capacitance tolerances are 1%, 2%, 5%, 10% and 20%. Plastic Capacitors, Chicago, Ill.

Circle No. 126 on Inquiry Card.

Variable Delay Line Box

Delay line box delivers any delay up to 0.79 usec with an accuracy of 0.8% of the maximum delay by means of binary switching. Reflections, ordinarily associated with variable delay lines, are eliminated because the unused portion of the delay line box is disconnected from the circuit by means of the switching arrangement. Rise time is 0.05 usec for the maximum delay and decreases as lesser delays are used. Impedance is 100 ohms and attenuation is 3.5%. Size is 3″ x 3″ x 5″. Valor Instruments Inc., Gardena, Cal.

Circle No. 193 on Inquiry Card

Temperature Control Without Contact

A new scientific instrument may alter existing temperature measurement and control techniques in many industries. Using advanced methods of infrared detection, a "Thermodot" radiation thermometer automatically measures and controls the temperature of moving or stationary objects without physical contact. Operation is completely remote and unattended. Radiation Electronics Co., Div. of Comptometer Corp., Chicago, Ill.

Circle No. 191 on Inquiry Card

New Mechanical Components For Electromechanical Systems

Universal Joints with Zero Backlash

A new, telescoping, miniature, universal joint allows greater freedom in the design of systems where the precise transmission of information is essential. Two preloaded ball splines provide lateral travel and a minimum amount of thrust on connected components. Preloaded bearing surfaces (burnished sockets and precision balls) with sealed-in lubrication give continuous contact. This design assures zero backlash for the entire assembly. Falcon Mach. and Tool, Cambridge, Mass.

Circle No. 168 on Inquiry Card

Diode Clips

Simpler component installation and replacement of "top-hat" diodes or rectifiers can now be achieved through the use of spring-tempered beryllium copper mounting clips. Circuit contact is provided by an integral lug passing through the mounting surface either for connection to printed circuit leads or for solder connection. Each clip pair exerts a strong retaining spring action on the body of the component, pressing the shell downward against a small projection in the clip which penetrates through films or oxides to clean metal, assuring circuit continuity under extreme conditions of stress. Atlee Corporation, Woburn, Mass.

Circle No. 196 on Inquiry Card

Mechanical Counter

A precision instrument counter, designed for digital read-out of shaft position, is a 5 digit, miniature, high speed, low torque device featuring nylon wheels and pinions for smooth and quiet operation. The counter is the direct drive type with the unit wheel directly coupled to precise read-out. A clear lucite cover with indicating lines is supplied which also keeps the unit free from dust. The counter has a rear shaft extension for direct coupling and is supplied on a standard mounting block with extra mounting holes for adjustment of the angle of the counter face. Specifications: Speed -1500 rpm continuous, 2500 rpm intermittent; Drive—Mechanical direct, either direction; Torque—Static torque 2 oz.—in. maximum; End Play—.012 maximum. Mechatrol, Div. of Servomechanisms, Westbury, L. I., N. Y.

Circle No. 178 on Inquiry Card.

Miniature Control Valve

Designed especially for use in small hydraulic circuits (under 3 gpm), a unique, new miniature four-way directional control valve with a sliding spool construction, is only 2" x 1½" x 5" (plus handle) and weighs one pound and two ounces. The new valve has a low pressure drop of approximately 13 psi at a rated capacity of 3 gpm and low internal leakage of less than 10 cubic inches per minute at 2000 psi with 150 ssu oil. The balanced spool is of hard-coated aluminum which provides great wear resistance. Sarasota Prec. Prods., Sarasota, Fla.

Circle No. 165 on Inquiry Card

Low Cost Instrument Bearings

New precision, miniature instrument bearings have been designed to replace precision ball bearings in a wide variety of applications where speed and torque requirements do not justify the cost of expensive ball bearings, but where precision instrument standards of tolerances, life and friction must be maintained. Made of sintered bronze per MIL-B-5687, Type I, Comp-A, with 4% molybdenum disulphide added at sintering, these bearings are oil-impregnated and completely self-lubricating. Tolerances may be specified equivalent to Class ABEC 5 or 7. Northfield Prec. Instrument Corp., Island Pk., L.I., N.Y.

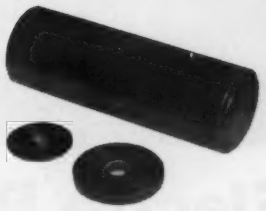
Circle No. 233 On Inquiry Card

Micro-Module Wafers

An accurate negative produced by photographic reduction, ultraviolet light, and an acid produce wafers quickly, accurately, and economically. A piece of special photosensitive glass and the negative of the micro-module wafer desired, is put under ultraviolet light making a contact print in the glass. A heat treating process develops the image of the pattern including every detail of design throughout the entire thickness of the glass. The image is highly receptive to acid etching which eats away the outlines and holes to leave an exact replica of the desired wafer. Further heat treatment converts the glass to a true ceramic. The wafers are non-porous, dimensionally stable and shock resistance. Corning Glass Works, Corning, N. Y.

Circle No. 222 on Inquiry Card.

BASIC BUILDING BLOCKS FROM KEARFOTT



FERRITES

Kearfott's Solid State Physics Laboratory formulates, fires and machines permanent magnet ferrite materials of various compositions. Typical high-efficiency array utilizes Kearfott PM-3 ferrite material with specially designed pole pieces to produce a design both smaller and lighter than other arrays of equivalent magnetic field strength. Because magnets may be custom engineered to specific requirements, user is not restricted to stock magnet types, thereby providing greater latitude in parameters for focusing arrays. Pole pieces may also be provided according to specification, with the added assurance that, because of special Kearfott design techniques, B axial magnetic fields approximately 10% higher than those generally obtained in standard types may be produced.

TYPICAL CHARACTERISTICS

Peak Magnetic Field Strength	1200 gauss
Period	0.560 in.
Length	5.64 in.
Inside Diameter of Pole Pieces	0.400 in.
Outside Diameter	2.0 in.
Weight	3.2 pounds

Write for complete data.

KEARFOTT DIVISION

GENERAL PRECISION INC.

LITTLE FALLS, NEW JERSEY

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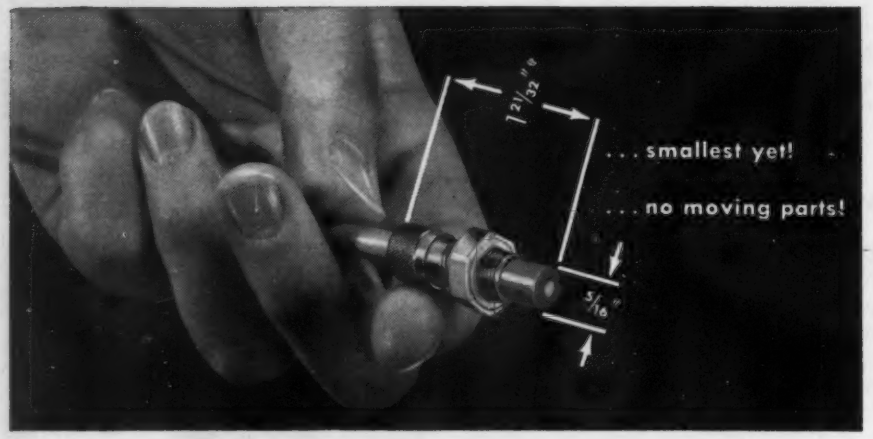

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Solves metal control problems where mechanical switches fail . . .

RELIABLE . . . unaffected by nearby 60 cycle AC fields.
LOW COST . . . replacement probes from $18.50.
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FAST . . . 60,000 operations/minute.
RUGGED . . . oil and waterproof.

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CIRCLE NO. 78 ON INQUIRY CARD

SILICONE SPONGE RUBBER SHEETS

Flexible temperature range -100°F to 500°F

COHRlastic R-10470 silicone sponge rubber sheets have a dense, uniform, non-absorbing closed cell structure highly suitable for soft gasketing, vibration dampening, fairing strips, pads, cushions and other applications where resiliency at extreme temperatures is required. It may be bonded to metals, plastics, fabrics or silicone rubber. COHRlastic R-10470 possesses superior compression set resistance, excellent dielectric properties, immunity to aging, ozone and weather hardening. Meets many specifications.

AVAILABLE FROM STOCK: in 12" x 12" sheets and 24" x 24" sheets — 1/16" through 1/2". Special thicknesses and sheet sizes up to 30" x 30" and 24" x 48" made to order. Sold nationally through distributors.

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Leader in Fabrication of Silicone Rubber Products

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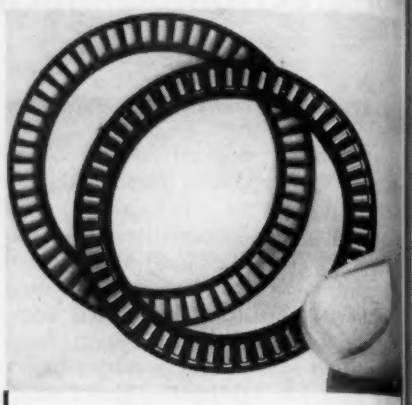

Bearing Cages

One of the newest uses for glass-filled nylon is in the manufacture of cages for thrust bearings. The cages are available for either roller or ball bearings and in a wide range of sizes. Chief among the many advantages of using glass-filled nylon is that tramp metal invading the bearing area imbeds itself into the plastic. This imbedment removes ordinarily loose metal particles from circulation, greatly reducing bearing abrasion and consequent wear of adjoining metal surfaces. If the bearing cage should fail, the problem of metal particle entrainment is obviated. Other significant advantages of the glass-filled nylon are: reduction of assembly time and initial material cost savings; molded-in retention cavities firmly position and hold round or shaped bearings, which are simply popped into the receptacles; excellent wear resistance; no lubrication required. Superior wear qualities and a wide temperature service range assure smooth, unhampered operation and greater bearing life. Garlock Packing Co., Palmyra, N. Y.

Circle No. 192 on Inquiry Card.

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3-bedroom and dressing room, 2½ bath, wall-to-wall carpeting, large living room, den and patio, year-new house. In Orange County, California, off Newport Avenue and Skyline Drive. On ½ acre on quiet, dead-end street, near schools and shops. All conveniences, appliances available. $32,500 OR $320/month. Excellent financing, if necessary. References exchanged. Available April 15th.

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BOOK REVIEWS

Resistance and Resistors

Charles L. Wellard
272 pages, $8.50
McGraw-Hill Book Co.,
330 W. 42nd St., N.Y. 36, N.Y.

Just about everything a components engineer needs to know in the basic aspects of resistance and in types of resistors and the materials used in their manufacture are in this reference and guidebook.

Electronic Designers' Handbook

Robert W. Landee, Donovan C. Davis, Albert P. Albrecht
1008 pages, $16.50
McGraw-Hill Book Co.,
330 W. 42nd St., N.Y. 36, N.Y.

This handbook serves as a fundamental aid in the design of all types of electronic equipment. The authors have made the text as lucid as possible and have included design examples to show application of theory, and graphical and tabular data needed in day-to-day design work. The authors believe that in many cases significant contributions have been made in the form of new design data or design techniques. The degree to which frequently used circuits and practices have been integrated into the material adds appreciably to the value of the book. The entire electronic field is covered ranging from vacuum tube and voltage and power amplifiers to such topics as computer and servomechanism techniques and waveform and network analysis.

Guide To The Space Age

Carl and Hazel Besserer
320 pages, $7.95
Prentice-Hall, Inc.,
70 Fifth Ave., N.Y. 11, N.Y.

Claimed to be the first book to explain in clear and simple language the terminology of modern space technology and guided missilery, its purpose is to help standardize the specialized language and to present the more than 5,000 definitions in a form that will be of value to technical and near-technical people. The terms are arranged in alphabetical order with a unique system of cross reference to guide the reader to the exact nomenclature and position of standard scientific terms.

Guided Missile Engineering

Allen E. Puckett and Simon Ramo
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Ronello B. Lewis
190 pages, $25.00
Prentice-Hall, Inc.,
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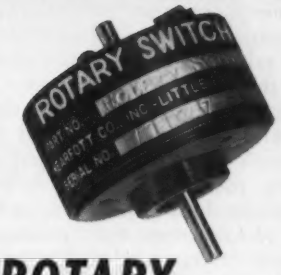
Financial Analysis for Management is a handbook for use by researchers, engineers and technicians as well as by top management men. It is a treatise on the finding of solutions to business problems that can be measured in terms of capital investment and dollar profit returns. From the point of view of the engineer, it provides an easy format to use in presenting projects for management approval where there is a requested appropriation of capital funds to be justified in terms of improved profits. From the point of view of management, it provides a medium that can be used as a standard in screning proposals for capital outlay arising in various parts of the business.

Thus, for the engineer, for the analyst, and for members of the management group, this book can serve as a common checkpoint. It is a reference

BASIC BUILDING BLOCKS FROM KEARFOTT



ROTARY SWITCH

Kearfott's rotary switching devices for missile and aircraft systems are used to sequence or switch circuitry as a function of time or shaft position. Used in conjunction with sensitive relays or solid state switching techniques, high current loads can be handled. These switches consist primarily of shaft assembly and bearing mounted cylinder divided into conducting and non-conducting segments with continuous track for common input. Multiple conductor "broom" type brushes ride on each cylinder track while number of tracks and segmentation of each is function of the number of circuits and type of "on-off" sequencing required.

TYPICAL CHARACTERISTICS P1280-11A

Number of switching tracks: 2

Angular Segmentation (both referenced to 0° start):
Track 1 — Non-conducting about 0° + 50°
Track 2—Conducting 0° -180°
Non-conducting 180° -0°

Mechanical Accuracy of Segmentation:
±1° (better as required)

Starting and Running Torque:
0.1 oz.-in.

Current Capacity:
50 ma at 28V/Brush (suitable for any sensitive relay or solid state switching circuits)

Write for complete data.

KEARFOTT DIVISION
GENERAL PRECISION INC.
LITTLE FALLS, NEW JERSEY
CIRCLE NO. 80 ON INQUIRY CARD

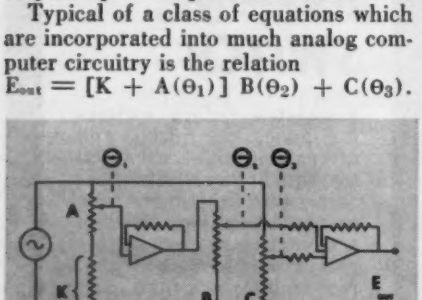
DESIGN IDEAS FOR ELECTRONIC ENGINEERS:

How to design better analog computing circuits with Vernistat* a. c. potentiometers

Analog computers typically use such components as potentiometers, resolvers, and linear synchros to relate shaft position to voltage. In most applications, to reduce the effect of loading error, high impedance circuits, and phase shift, a substantial amount of additional equipment, such as isolation amplifiers and auxiliary power supplies, is required. Size, weight, heat dissipation, and possibility of failure are thus greater than if loading error, phase shift, and high output impedance problems did not exist.

Typical of a class of equations which are incorporated into much analog computer circuitry is the relation

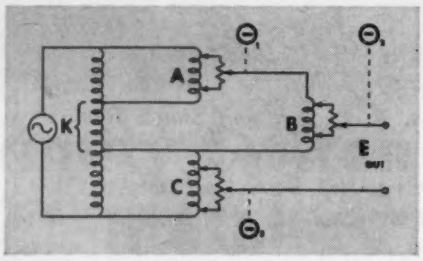
$E_{out} = [K + A(\Theta_1)]\, B(\Theta_2) + C(\Theta_3)$.



ONE WAY TO SOLVE this relation is shown in this diagram of a conventional resistance potentiometer computing circuit. Such circuits, however, suffer from excessive phase shift, particularly at high frequencies.

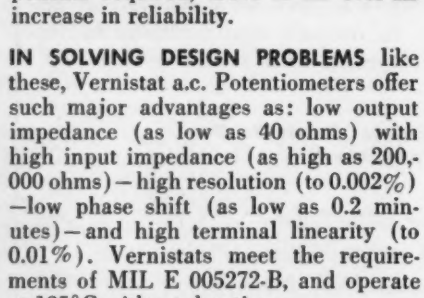
Due to high potentiometer output impedances, the circuit requires an isolation amplifier in the multiplying channel, while summing resistors and a feedback amplifier are required in the addition section. Both of these amplifiers, as additional components, add a factor of unreliability and use more power, increasing the problem of heat dissipation.

A MORE EFFICIENT WAY TO SOLVE this equation is with Vernistat a.c. Potentiometers. The Vernistat is an ideal component for analog computer systems. Its combination of a tapped autotransformer and an interpolating potentiometer uniquely provide characteristics unobtainable with other types of shaft position-voltage devices. The Vernistat provides precise voltage division, high input impedance, low output impedance, and low phase shift. These characteristics directly relate to the design of improved computer circuits.



FOR EXAMPLE, in the computer circuit shown here, multiplication may be performed without the aid of an isolation amplifier, because of the Vernistat's high ratio of input to output impedance. Addition is accomplished by utilizing voltages of opposite phase in the two computing channels obtained by a tapped input transformer. By eliminating the amplifiers of the preceding circuit, a reduction of size, weight, heat rise, and power requirements is obtained. With fewer components required, there is an over-all increase in reliability.

IN SOLVING DESIGN PROBLEMS like these, Vernistat a.c. Potentiometers offer such major advantages as: low output impedance (as low as 40 ohms) with high input impedance (as high as 200,000 ohms)—high resolution (to 0.002%)—low phase shift (as low as 0.2 minutes)—and high terminal linearity (to 0.01%). Vernistats meet the requirements of MIL E 005272-B, and operate at 125°C without derating.



WRITE TODAY for full description and specifications on Vernistat a.c. Potentiometers, Adjustable Function Generators, and Variable Ratio Transformers.

AT THE IRE SHOW, VISIT US IN BOOTH 2828

*vernistat® — *a design concept that unites in one compact device the best features of the precision autotransformer and the multiturn potentiometer*

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768 Main Avenue, Norwalk, Conn.

Perkin-Elmer *Corporation*

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BOOK REVIEWS cont.

book for all. Its language is nontechnical. There is no jargon and no secret formulae are involved. It is a book filled with plain talk, expressed in the language of every man. Its objective is profit. And since profit is measured in dollars and cents, a certain amount of arithmetic is involved.

The highlight of this text is the so-called "incremental" approach under which the differences in profit between two or more possible alternatives are matched against the differences in investment, again for the same alternatives, to establish a ratio of incremental profit-to-investment. The increment is nothing more than the effect or the difference between two alternatives. The increment of profit divided by the increment of investment gives the incremental profit return, which is the common measure in all financial analyses.

These simple relationships are expressed by the author in what is called the Rule-of-Seven—because essentially every financial analysis revolves around seven key figures, involving these steps:

- *Measure investment now*
- *Measure investment as projected*
- *Effect of the proposal*
- *Measure profit now*
- *Measure profit as projected*
- *Effect of the proposal*
- *Measuring percent return*

These seven steps are covered in detail in the first six chapters of the book in the areas dealing with an appraisal of proposed capital expenditures. For those who want to dig deeper, the second half of the book treats the more complicated investor's method of measuring return and provides chapters dealing with the purchase or acquisition of a going business, mergers for growth and increased profit, adding or dropping lines or segments, inter-divisional pricing, leases and leasebacks versus ownership, and planning the source of funds.

The text material provides a background for financial analysis, but the salient feature of the book and its value to the reader are found in the numerous life-size exhibits. These illustrate in form and substance the treatment of numerous problems of analysis, all fully supported by figures and examples, interconnected from one situation to the next, to give the reader a pattern or approach that can be used over and over again in the solution of similar problems that may fall within his own experience.

BASIC BUILDING BLOCKS FROM KEARFOTT

DIRECTIONAL GYRO

This compact new gyro provides accurate heading information even under the severe conditions of environment frequently encountered in high performance aircraft and missile installations. Inner axis leveling loop, consisting of a liquid bubble type vertical sensor and A.C. torquer, continuously maintains the spin axis in a horizontal plane.

TYPICAL CHARACTERISTICS #A2215

Environmental Capabilities
Vibration:
5g, 20-1000 cps; 10g, 1000-2000 cps
Temperature Range (operative):
—54°C to +71°C
(non-operative):
—65°C to +85°C
Altitude: Unlimited

Azimuth Pickoff
Excitation:
26V, 400 cps, single phase
Output (sinusoidal):
11.8V ± 5% max.
Error from E.Z.: 10 min. max.

Motor
Excitation:
115V, 400 cps, three phase
Speed: 23,500 RPM
Power: Starting: 35 watts
Running: 7.5 watts

Performance Characteristics
Drift: 4°/hr. max.
Leveling Rate:
Between 2° and 4°/min.
Azimuth Torquing Rate:
360°/min. (intermittent)
40°/min. (continuous)

Physical Features
Dimensions: 4" dia. x 5 3/16" long
Weight: 5.5 lbs. (approx.)

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

VERTICAL GYRO

Kearfott's rugged new vertical gyro, designed for missile application, is a two-degree-of-freedom instrument with 360° of freedom about outer gimbal axis. Self-contained vertical erection system incorporates liquid bubble-type vertical sensing device.

TYPICAL CHARACTERISTICS #B2115

Environmental Capabilities
Vibration:
5 g, 20-1000 cps;
10 g, 1000-2000 cps
Temperature Range (operative):
—54°C to +71°C
(non-operative):
—65°C to +85°C
Altitude: Unlimited

Pickoffs
Excitation:
26V, 400 cps, single phase
Error from E.Z.: 10 min. max.
Output Voltage (line to line):
11.8V ± 5% max.

Motor
Excitation:
115V, 400 cps, three phase
Power: Starting: 35 watts
Running: 7.5 watts

Performance Characteristics
Repeatability of Established Vertical:
To within a cone of half angle equal to 12 minutes of arc
Scorsby Drift Rate in 5 Min. Time:
0.3°/min. (average)
Erection Rate:
Normal: Between 2° and 4°/min.
Fast: 80°/min. intermittent,
40°/min. continuous

Physical Features
Dimensions: 4" dia. x 5 3/16" long
Weight: 5.5 lbs. (approx.)

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

FREE GYRO

A highly reliable, two-degree-of-freedom instrument utilizing AC synchros at each gimbal axis. Designed to operate under the most severe missile conditions, this gyro has AC torquers mounted at each gimbal axis to permit command positioning or slaving of spin axis to desired reference position; each torquer capable of producing a precession rate of 360°/minute with 12.5 watts/phase power input.

TYPICAL CHARACTERISTICS #Q2315

Environmental Capabilities
Temperature Range:
(operative): — 54°C to +71°C
(non-operative): —65°C to +85°C
Altitude: Unlimited
Vibration: 10g, 10-2000cps

Pickoffs
Excitation:
26V, 400 cps, single phase
Output (sinusoidal):
11.8V ± 5% max.
Error from E.Z.: 10 min. max.

Motor
Excitation:
115V, 400 cps, three phase
Speed: 23,500 RPM
Momentum:
2.25 x 10^6 gm cm^2/sec.

Caging and Preset Provision
(Electrically energized torquer type)
Excitation: 115V max./phase
Torquer Constant:
22.8 dyne cm/$Volt^2$

Performance Characteristics
Free Drift:
0.5°/minute each axis
Runup Time:
1 minute max.
Torquing Rate:
360°/min. (intermittent)
40°/min. (continuous)

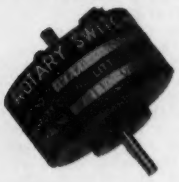
Physical Features
Dimensions: 4" dia. x 5 3/16" long
Weight: 5.5 lbs. (approx.)

Write for complete data.

Synchronous Motor

Ferrites

Rotary Switch



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For Your 3-Ring Binder

NEW DATA SHEETS

For your free copy of the data sheets listed on this page, circle the appropriate number of the item on the Inquiry Card.

Transistorized Decades 171

Miniature, transistorized plug-in decimal counters feature high operating speed, simple power-supply requirements, low power consumption, repairability, and reserve reliability. The circuits were designed using saturation techniques, along with consistent derating of component tolerances, and will work dependably even under adverse conditions of environment and power supply variations. The standard conservative counting rates are 0-250 kc and 0-5 mc. Specification, selection and application guides are included in data. Engineered Electronics Co., Santa Ana, Cal.

Temperature Controls 142

Catalog sheet describes surface mounting temperature controls. Three types are featured: two for the 50-300°F range; one for 50-600°F. All units are adjustable. Complete specifications are given along with details on 11 different modifications. Fenwal Inc., Ashland, Mass.

Wound Wire Porous Metal 185

Six-page brochure details the capabilities and typical examples of wound wire porous metal for filtration and non-filtration applications. Included are examples of stainless steel and super alloy Poroloy and low-cost Poroloy CS which is made from low alloy and carbon steels, specifications and curves for flow rate and physical characteristics. Bendix Filter Div., Madison Hgts., Mich.

Resistor Power Nomographs 149

Power nomographs, which enable design engineers to predict accurately the long-term performance of composition fixed resistors are included in an 8-page bulletin. The information shows how power input, temperature rise, ambient temperature, life, and permanent resistance change are interrelated for the composition resistors. The nomographs are arranged so that resistor performance can be predicted over periods from 100 hours to 100 years under various operating conditions. Four typical examples are included to illustrate the use of these power nomographs and the types of information that can be obtained. Allen-Bradley Co., Milwaukee, Wis.

Relays 163

Data Sheets are provided for three basic types of relays: 5 amp series; 10 amp series; and specialty relays. The folder also covers a new crystal can relay, a ruggedly constructed device housed in an enclosure only slightly larger than the conventional crystal can and which contains a switching mechanism capable of handling 10 amp loads for 100,000 operations with a 40 amp overload rating. Of particular interest also is data on a line-mounted relay which provides connections at its opposite ends so that when it is mounted in a run of electrical cable it becomes an integral part of the line. Thus mounted it has 100g vibration and shock characteristics. Relay Division, Electronic Specialty Co., L. A., Cal.

High Speed Vacuum Pumps 180

Brochure contains operating principles, features and specifications of Roots high vacuum pumps. The outstanding feature of these pumps is that very high pumping speeds can be obtained with comparatively small external pump dimensions. Consolidated Vacuum Corp., Rochester, N. Y.

Clutch–Gear Motors 145

High starting torque, fast disengagement time of 25 milliseconds, speeds from 4 to 328 rpm, low noise level and easy mounting are some of the features of fractional hp clutch-gear motors. Data sheets give full specifications. Molon Motor And Coil Co., Rolling Meadows, Ill.

Cradleclip Wiring System 173

Six-page brochure details the range of types, sizes, and costs of an expanded cradleclip wiring system. Designed for either retaining cable runs or mounting components from ⅛" to 2" in diameter, the system includes both cradles for supported mountings and binders for control of unsupported wire or cable runs. The units are made of nylon and neoprene and usable within a temperature range of —76°F to +212°F. Electrovert, Inc., New York, N. Y.

Environmental Testing 164

Brochure contains description and capacities of apparatus required for military and commercial testing of electronic equipment, to measure shock and vibration, temperature, altitude, humidity, salt spray, sand and dust, pressure, submersion and electronic radiation. Test equipment is capable of meeting requirements for most current military specifications. Stavid Engineering, Inc., Plainfield, N. J.

Pushbutton Switch Assemblies 176

Eight-page data sheet introduces three new "one-shot" pushbutton switch assemblies that have a special circuit to produce one square wave pulse regardless of operating speed. Variations are available with pulse widths from 0.1 to 10.0 microseconds. Data sheets contain circuit diagrams, tables, graphs of typical output pulse curves, and other pertinent information. Micro Switch, Freeport, Ill.

Mechanical Shaft Seals 148

4-page folder describes two new designs in water pump shaft seals for low pressure applications. One type is a self-contained, single unit seal designed for quick and easy installation. The other design is a cartridge type unit seal which does not touch the shaft and is unaffected by shaft speed variations and normal vibration. Data includes space requirements, typical applications, a brief explanation of the sealing principle behind rotary seals and normal seal components. Rotary Seal Div., Muskegon Piston Ring Co., Sparta, Mich.

Servo Actuator 211

Specifically designed for control surface actuation in supersonic flight where exceptionally high-response closed-loop positioning systems are required, a servo actuator contains the magnetic-particle clutches, driven by a continuous-duty 26vdc motor, geared to a common shaft through a precision gear train. Linkage to desired control is made through an arm, limited in stroke by integral stops to 40° ±1° either side of neutral. Description and specifications are given in a data sheet. Lear Instrument Div., Grand Rapids, Mich.

Compact AC Timing Motors 138

Compact, reversible ac timing motors are supplied with built-in gear trains offering speeds from 450 rpm down to ¼ rph. The synchronous characteristic of these hysteresis type motors assures an accuracy on the same order as the power source, with reliable operation assured through sound design and rugged construction. Operation can be on single phase supplies, using a phase shift network supplied with one winding, or on two phase supplies. A. W. Haydon Co., Waterbury, Conn.

Corrosion Resistant Alloys 140

Bulletin on tubing and pipe made of Hastelloy Alloys B and C outlines applications of these super corrosion resistant alloys and describes their resistance to corrosive fluids. Tables show the comparative resistance of the alloys to various corrosive media at specified concentrations and temperatures. Other tables show the chemical analysis and physical and mechanical properties of the two alloys, as well as size ranges available and tolerances of pipe and tubing. Carpenter Steel Company, Alloy Tube Division, Union, New Jersey.

Phototransistors 150

8-page brochure describes complete line of PNP germanium alloy junction phototransistors which combine high speed response and high sensitivity. Included are: maximum ratings; cut-off and small signal characteristics; mechanical data; light sensitivity; chopped light frequency response; photo spectral response; noise considerations; typical circuit applications and response curves. General Transistor Corporation, Jamaica, New York.

Metals and Alloys 130

Eight-page brochure discusses metals and alloys for use in conjunction with semiconductor products. New alloys of gold, platinum and other metals in the form of wire, sheet, or stamped products are described as well as electroplated wire and strip and rhodium and gold plating solutions. Sigmund Cohn Corp., Mount Vernon, New York.

Multi-Conversion System 136

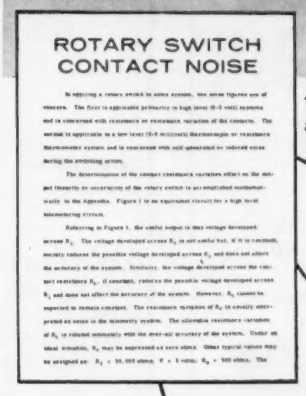
A completely transistorized highly accurate, high speed voltage-to-digital digital-to-voltage conversion system is small in size and requires little power. The speed of operation in translating a voltage to a number varies with the accuracy of conversion. A 14-bit conversion at an accuracy of 0.01% requires approximately 60 microseconds, while an 11-bit conversion at an accuracy of 0.05% requires 48 microseconds. Brochure contains modes of operation, input and output characteristics and other pertinent information. Packard Bell Computer Corp., L. A., Cal.

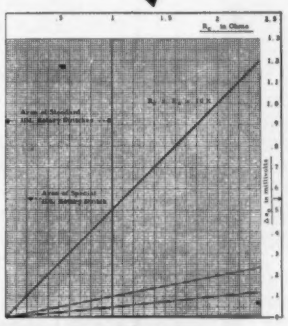
Miniature Tape Recorder 137

New two-channel tape recorder measures only 5" by 4" by 2" complete, including all electronics. Total weight is 2 pounds. All applicable portions of MIL-E-4158A for ground applications are met but the recorder can also be furnished for special flight and other applications. Power requirements are only 2½ watts (dc source). The tiny recorder will operate at any tape speed up to 48 ips, bi-directional with end-of-tape sensing. Frequency response is up to 100 kc, ± 3 db at 48 ips.. Precision Instrument Co., San Carlos, California.

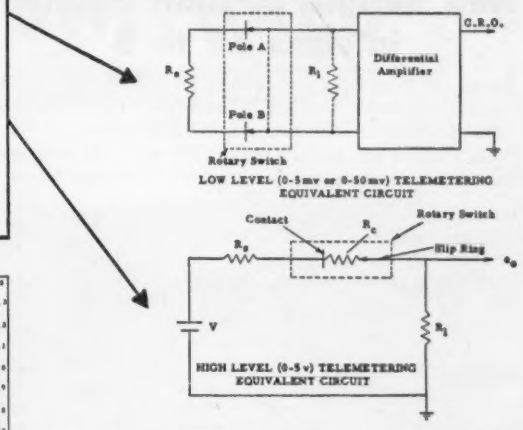
How Do YOU Define Switch Noise?

Here's how IDL analyzes it!

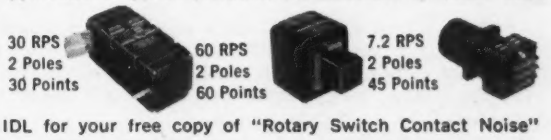




These data are important considerations in switch applications and provide you with valuable criteria for systems evaluation.



IDL quality control and inspection procedures insure that these "Standards of Excellence" are maintained in the production of high speed, sealed rotary switches for critical applications. Typical products are indicated by these units.



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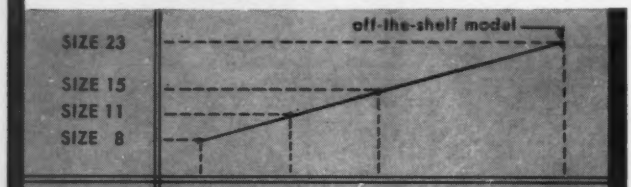
OPTISYNS

New designs of shaft encoder in sizes 23 to 8

Dynamics Research Corporation's OPTISYN Incremental Digital Shaft Angle Encoder is available in resolutions up to one part in 2^{11} (2048) in a 2.312 inch case.

New designs of special OPTISYNS with the maximum resolution versus case size are available as shown below.



Counts/rev	100 128	500 512	1000 1024	decimal binary	2000 2048
Binary Value	2^7	2^9	2^{10}		2^{11}
Angle (minutes)	160	40	20		10

These special OPTISYN units offer the advantages of the standard size 23 OPTISYN, i.e., fast pulse rate (100,000 pulses/sec.), high reliability, and elimination of brushes. Also, size, weight and inertia are appreciably reduced.

Send your requirements for engineering recommendations.

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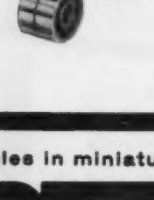

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MINIATURE PRECISION BEARINGS INC.

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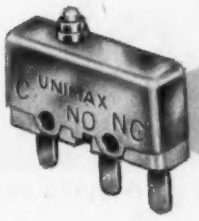
SUBMINIATURE

HIGH-TEMPERATURE SWITCHES

for continuous full-load service at high ambient temperatures.



650°F

FC-1
Full electrical rating applies from −65 to +650F. Metal cover, Mycalex base, welding-tab or threaded-stud terminals.

400°F

USM4
Case and button molded of heat-resistant material; stainless-steel operating mechanism.

275°F

USM5
Meets MIL-S-6743 and Military Drawing MS-25085.

ELECTRICAL RATING
single-pole double-throw

FC-1 4 amp. 18-30 v.d-c, resistive
2.5 amp. 18-30 v.d-c, inductive

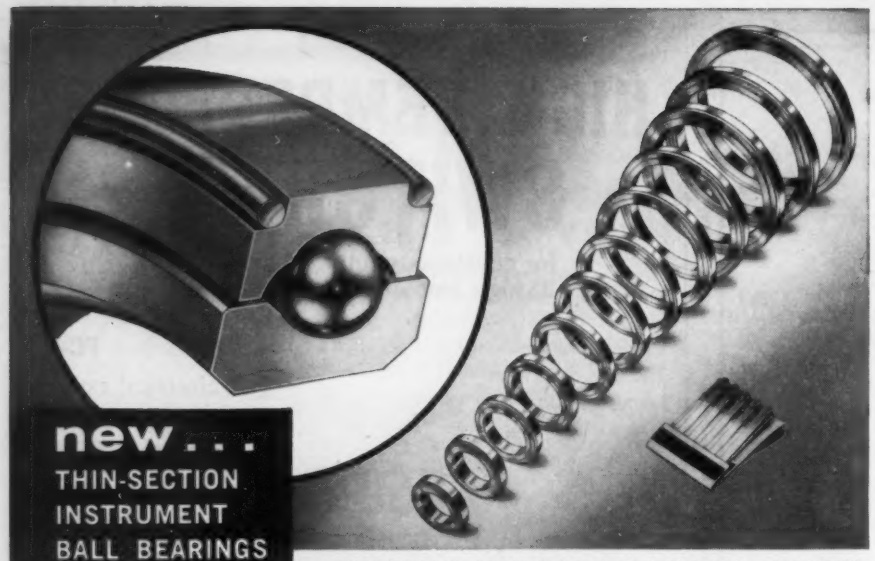
USM4 5 amp. 125/250 v.a-c
5 amp. 30 v.d-c, resistive
3 amp. 30 v.d-c, inductive

USM5 5 amp. 125/250 v.a-c
5 amp. 30 v.d-c, resistive
3 amp. 30 v.d-c, inductive

Ask for Catalog 159A.

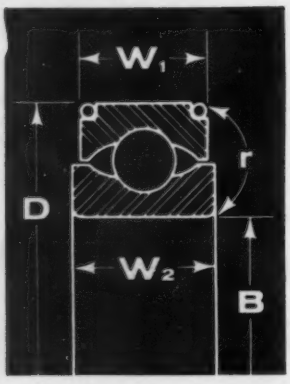
UNIMAX SWITCH
Division, The W. L. Maxson Corporation
IVES ROAD, WALLINGFORD, CONNECTICUT

CIRCLE NO. 89 ON INQUIRY CARD



PRECISION AND ULTRA-PRECISION GRADES

TYPE TWF WITH INTEGRAL SHIELDS



A thin-section radial ball bearing with integral shields on both sides. Deep groove ball races with continuous shoulders, uninterrupted by filling slots. Maximum radial and thrust capacity possible in a radial ball bearing of its dimensions. The close-clearance annulus between shields and inner ring fills with lubricant and functions as an effective seal without the objectionable torque found with contact seals. This design in a precision instrument bearing is possible only with the Split Ballbearing method of construction. Also made in type TWA with alternate balls slightly undersize, for lower torque applications.

Balls and rings are 52100 high chrome alloy bearing steel. Also available in 440 C stainless.

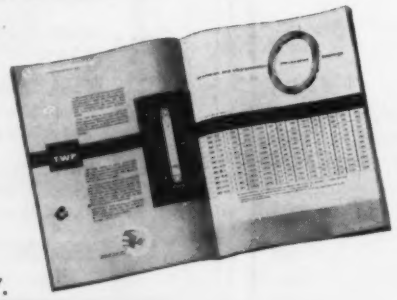
number	*B bore	*D o.d.	W_1 +.000 −.005	W_2 +.000 −.005	Balls no.	Balls size	wt. lbs.	‡L lbs.	§S lbs.
TWF 10-17	.6250	1.0625	.250	.281	24	7/64	.042	276	500
TWF 12-19	.7500	1.1875	.250	.281	24	1/8	.047	354	650
TWF 14-21	.8750	1.3125	.250	.281	27	1/8	.052	375	730
TWF 17-24	1.0625	1.5000	.250	.281	32	1/8	.06	435	870
TWF 21-28	1.3125	1.7500	.250	.281	38	1/8	.07	440	1030
TWF 25-32	1.5625	2.0000	.250	.281	44	1/8	.08	470	1200
TWF 29-36	1.8125	2.2500	.250	.281	50	1/8	.09	490	1360
TWF 33-42	2.0625	2.6250	.250	.281	58	1/8	.14	520	1580
TWF 37-46	2.3125	2.8750	.250	.281	64	1/8	.16	545	1740
TWF 41-52	2.5625	3.2500	.312	.375	48	3/16	.24	1010	2900
TWF 45-56	2.8125	3.5000	.312	.375	52	3/16	.28	1040	3150
TWF 49-62	3.0625	3.8750	.312	.375	58	3/16	.32	1100	3500

Dimensions are in inches. Radius "r" will clear .015" shaft or housing fillet. *Tolerances vary according to size — see catalog 59 for Precision Grade and Ultra-Precision Grade Tolerances. ‡Radial load capacity at 500 rpm and 2500 hours average life. §Static non-brinell load capacity.

send for new catalog 59

Split's catalog 59 provides complete coverage on the complete T series of thin-section precision instrument ball bearings. No designer should be without it.

WRITE FOR YOUR COPY TODAY.



split ballbearing
A DIVISION OF MPB, INC.
521 HIGHWAY FOUR, LEBANON, NEW HAMPSHIRE

CIRCLE NO. 90 ON INQUIRY CARD

Miniature Switches 17

Operating characteristics are given on a complete line of switches including minia ture, sub-miniature, open blade, gener purpose, metal clad and machine tool type Several types of relays also are describe in the 4-page brochure. Acro Div., Rober shaw-Fulton Controls Co., Columbus, Ohi

High Vacuum Pumps 15

Three 14-page instruction booklets cov the installation, operation and maintena of high vacuum pumps. One booklet cove two-stage, series-connected mechani pumps that use the internal vane princip A rotary type, oil-sealed unit which ope ates on the principle of the eccentric ro with external moving vane, is describe in another booklet. The 3rd manual co tains instructions for a combinati vacuum and pressure unit with a rat vacuum of 15 microns and providing pre sures to 10 psi. Each booklet contai detailed specifications, diagrammatic drawings and descriptions of accesso equipment. Central Scientific Compan Chicago, Illinois.

Size 8 Servomotors 14

Complete electrical and mechanical spec fications, outline drawings, schematics a torque-speed curves are presented servomotors, servomotor-rate generat inertia-damp and adjustable velocity-da servomotors in 115-volt, 400-cycle a 26-volt, 400-cycle versions. Helipot Divisi of Beckman Instruments, Inc., Fullert California.

Inertial Guidance Testing 1

Brochure includes descriptions and spec fications of rate turntables for testi gyros, antennas, seekers, accelerometer and guidance assemblies. Sterling Preci Corp., Port Washington, L. I., N. Y.

Digital Test Equipment 2

Logical interconnections between units a made with patch cords using miniatur stacking banana jacks, and all logic signals are available on the graphic fro panels of the units. Standard power co nections are made through the plug- back panels. As a result, the units can b connected and disconnected with the utmo ease and speed. Folder describes characteristics. Digital Equipment Cor Maynard, Mass.

Dielectric Materials 20

Condensed listing of a complete line d dielectric materials, including castin resins, foams, absorbers, adhesives, im pregnants, coatings, ceramics and refle tors. Many uses of these products ar pictured. A chart gives data on variou standard resins. Emerson & Cuming Inc. Canton, Mass.

Miniature Pulse Transformers 16

Detailed description of miniature pul transformers for blocking oscillator pul coupling, inverting and impedance matchi is outlined in a bulletin. Pulse width, ri time, pulse induction, dc resistance, im pedance ratio and four types of packagi are explained. The transformers are bu to Mil T27A and are offered in sever different winding configurations. Val Instruments Inc., Gardena, Cal.

Relays 17

Engineering specifications folder contai operating characteristics and complete da for hundreds of different relays of vari types—sensitive, antenna, medium powe hermetically sealed, telephone and micr miniature. Kurman Electric Co., Brook lyn, New York.